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COMPARISON OF DIESEL EXHAUST EMISSIONS USING JP-8 AND LOW-SULFUR DIESEL FUEL

INTERIM REPORT
TFLRF No. 308

By

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For

Headquarters
Department of the Army
The Pentagon
Washington, D.C.

Under Contract to

U.S. Army TARDEC
Mobility Technology Center–Belvoir
Fort Belvoir, Virginia

Contract No. DAAK70-92-C-0059

November 1995

Disclaimers

DTIC Availability Notice

Disposition Instructions

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	November 1995	Interim March 1994 to March 1995

4. TITLE AND SUBTITLE

Comparison of Diesel Exhaust Emissions Using JP-8 and Low-Sulfur Diesel Fuel

5. FUNDING NUMBERS

DAAK70-92-C-0059; WD 28

6. AUTHOR(S)

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

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8. PERFORMING ORGANIZATION REPORT NUMBER

TFLRF No. 308

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Department of the Army
Mobility Technology Center-Belvoir
10115 Gridley Road, Suite 128
Ft. Belvoir, Virginia 22060-5843

Headquarters
Department of the Army
The Pentagon
Washington, D.C. 20310-0103

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

Comparative emission measurements were made in two dynamometer-based diesel engines using protocol specified by the U.S. Environmental Protection Agency (EPA) and the California Air Resources Board (CARB). A single JP-8 fuel with a sulfur level of 0.06 wt% was adjusted to sulfur levels of 0.11 and 0.26 wt%. The emission characteristics of the three fuels were compared to the 1994 EPA certification low-sulfur diesel fuel (sulfur level equal to 0.035 wt%) in the Detroit Diesel Corporation (DDC) 1991 prototype Series 60 diesel engine and in the General Motors (GM) 6.2L diesel engine. Comparisons were made using the hot-start transient portion of the heavy-duty diesel engine Federal Test Procedure.

Results from the Army study show that the gaseous emissions for the DDC Series 60 engine using kerosene-based JP-8 fuel are essentially equal to values obtained with the 0.035 wt% sulfur EPA certification diesel fuel, and that an approximate sulfur level of 0.21 wt% in kerosene-type JP-8 fuel would be equivalent to the 0.035 wt% sulfur reference fuel. Similarly, the regulated gaseous emissions for the GM 6.2L engine using JP-8 fuel are essentially equal to the values obtained with the 0.035 wt% sulfur EPA reference fuel. All sulfur levels of kerosene-type JP-8 fuel up to the 0.30 wt% MIL-T-83133 specification maximum would be equivalent to a 0.035 wt% sulfur EPA reference fuel.

14. SUBJECT TERMS

Emissions	Fuel sulfur	Hot-start transient
Gaseous emissions	Diesel fuel	FTP
Particulate emissions	Kerosene	EPA
JP-8	Heavy-duty diesel	

15. NUMBER OF PAGES

123

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

EXECUTIVE SUMMARY

Problems: The U.S. Army has adopted the strategy of a "single fuel" for the battlefield that provides distinct military advantages in training for and execution of combat operations. Aviation kerosene fuel, MIL-T-83133C grade JP-8, having a maximum allowable sulfur content of 0.30 weight percent (wt%) is the "single fuel" specified by the Army. However, a U.S. Environmental Protection Agency (EPA) regulation effective 01 October 1993 restricted the sulfur content in diesel fuel for on-highway use to a maximum of 0.05 wt%, which has effectively denied Army use of JP-8 on the highways. Since the Army believed that kerosene-based fuels such as JP-8 were likely to produce lower diesel exhaust emissions (especially particulate matter) than typical distillate fuel emissions (i.e., from No. 2 diesel), an experimental program was conducted by the Army to verify this belief.

Objective: The objective of this project was to compare the diesel exhaust emissions of kerosene-based JP-8 fuel to low-sulfur diesel fuel.

Importance of Project: The Detroit Diesel Corporation (DDC) 1991 Series 60 engine is specified in the EPA and California Air Resources Board (CARB) protocol, and the General Motors (GM) 6.2L engine is typical of the engine used in the Army's family of over 100,000 light-duty tactical and commercial wheeled vehicles. These two engines were chosen to compare the effect of JP-8 fuel sulfur on exhaust emissions with a reference diesel fuel. The intent of the fuel emission comparisons was to show that three JP-8 fuels of varying sulfur levels would have essentially no effect on the gaseous emissions (e.g., unburned hydrocarbons, carbon monoxide, and oxides of nitrogen) but would in fact show decreases in particulate matter compared with the EPA reference fuel. The goal of the study is consistent with the fact that the EPA considers the impact of sulfur content in diesel fuel to be significant in the alteration of engine particulate matter emissions and considers fuel sulfur to have no effect on regulated gaseous emission response.

Technical Approach: Comparative emission measurements were made in two dynamometer-based diesel engines using protocol specified by the EPA and CARB. A single JP-8 fuel with a sulfur level of 0.06 wt% was adjusted to sulfur levels of 0.11 and 0.26 wt%. The emission characteristics of the three fuels were compared with the 1994 EPA certification low-sulfur diesel fuel (sulfur level equal to 0.035 wt%) in the DDC 1991 prototype Series 60 diesel engine and in the GM 6.2L diesel engine. Comparisons were made using the hot-start transient portion of the heavy-duty diesel engine Federal Test Procedure.

Accomplishments: Results from the Army study show that the gaseous emissions for the DDC Series 60 engine using kerosene-based JP-8 fuel are essentially equal to values obtained with the 0.035 wt% sulfur EPA certification diesel fuel, and that an approximate sulfur level of 0.21 wt% in kerosene-type JP-8 fuel would be equivalent to the 0.035 wt% sulfur reference fuel. Similarly, the regulated gaseous emissions for the GM 6.2L engine using JP-8 fuel are essentially equal to the values obtained with the 0.035 wt% sulfur EPA reference fuel. All sulfur levels of kerosene-type JP-8 fuel up to the 0.30 wt% MIL-T-83133 specification maximum would be equivalent to a 0.035 wt% sulfur EPA reference fuel.

Military Impact: While the military's kerosene-based JP-8 specification allows for sulfur levels up to 0.30 wt%, the actual sulfur level of 93 samples obtained in an Army survey was 0.07 wt%. In another survey, JP-8 sulfur averaged 0.03 wt% at Ft. Bliss, TX, during a 21-month period (October 1989 through June 1991). A recent Defense Fuel Supply Center survey of 182 JP-8 fuels delivered to military installations within the continental United States indicated the average JP-8 sulfur level to be 0.03 wt%. When one considers the results of the Army engine fuel emissions study coupled with the reality of actual JP-8 sulfur levels, it is reasonable to conclude that Army use of JP-8 on highway applications will have little effect on diesel regulated gaseous emissions but will be expected to lower exhaust particulate matter emissions in the diesel-powered fleet.

FOREWORD/ACKNOWLEDGEMENTS

This work was performed by the U.S. Army TARDEC Fuels and Lubricants Research Facility (TFLRF) located at Southwest Research Institute (SwRI), San Antonio, TX, in cooperation with the Department of Emissions Research at SwRI during the period March 1994 to March 1995 under Contract No. DAAK70-92-C-0059 with the U.S. Army TARDEC, Mobility Technology Center-Belvoir (MTCB). Mr. T.C. Bowen (AMSTA-RBFF) served as the MTCB contracting officer's representative, and Mr. M.E. LePera (AMSTA-RBF) served as the MTCB project technical monitor. Cooperative funding for this effort was provided by the Department of the Army (DA), The Pentagon. Col. W. Kabat (DALO-TSE) served as the DA technical monitor.

The authors would like to acknowledge the assistance provided by Ms. M.M. Clark in report preparation.

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I. INTRODUCTION

The use of MIL-T-83133C grade JP-8 by the U.S. Army as the single battlefield fuel (1)* was thought to have a potential benefit of being more environmentally friendly than diesel fuel. Kerosene-based JP-8 consists of lower molecular weight hydrocarbons, lower end boiling point, and until recently, lower fuel sulfur content than typical distillate-based diesel fuels. These factors led to reduced particulate and smoke emissions from diesel engines and was the primary reason aviation kerosene-based fuel was chosen by urban transit companies for inner city routes.(2)

Because the MIL-T-83133C specification (3) for grade JP-8 allows a maximum fuel sulfur content of 0.30 weight percent (wt%), the U.S. Environmental Protection Agency (EPA) would not allow JP-8 to be utilized as an on-highway fuel. A worldwide survey of 93 kerosene fuel samples revealed an average sulfur content of 0.07 wt%.(4, 5) During a JP-8 demonstration program at Ft. Bliss, TX, the average delivered JP-8 fuel sulfur content was 0.03 wt% over a 21-month period from October 1989 through June 1991.(6, 7) A Defense Fuel Supply Center (DFSC) survey of 182 JP-8 fuel deliveries to military installations within the continental United States indicated the sample average JP-8 sulfur level to be 0.03 wt%.(8) As shown in Fig. 1, 85 percent of the JP-8 delivery samples had sulfur levels at or below 0.05 wt%. Data from the Petroleum Quality Information System of DFSC indicates the volume weighted sulfur of 1994 JP-8 deliveries was 0.044 wt%, with 75 percent of all shipments containing 0.05 wt% sulfur or lower (as shown in Fig. 2).(9) Available data suggest that although JP-8 may contain up to 0.30 wt% sulfur, it rarely does so. In fact, most JP-8 deliveries appear to satisfy the 0.05 wt% sulfur EPA requirement for on-highway diesel fuel. However, with the advent of the 01 October 1993 EPA regulation mandating a maximum on-highway diesel fuel sulfur content of 0.05 wt%, the refiners of JP-8 have been unwilling to guarantee that all deliveries of JP-8 will meet the EPA low-sulfur fuel requirement.(10)

The EPA specification of 0.05 wt% maximum sulfur content resulted from data generated with full boiling range diesel fuels. The sulfur specification level for diesel fuels was determined to

* Underscored numbers in parentheses refer to the list of references at the end of this report.

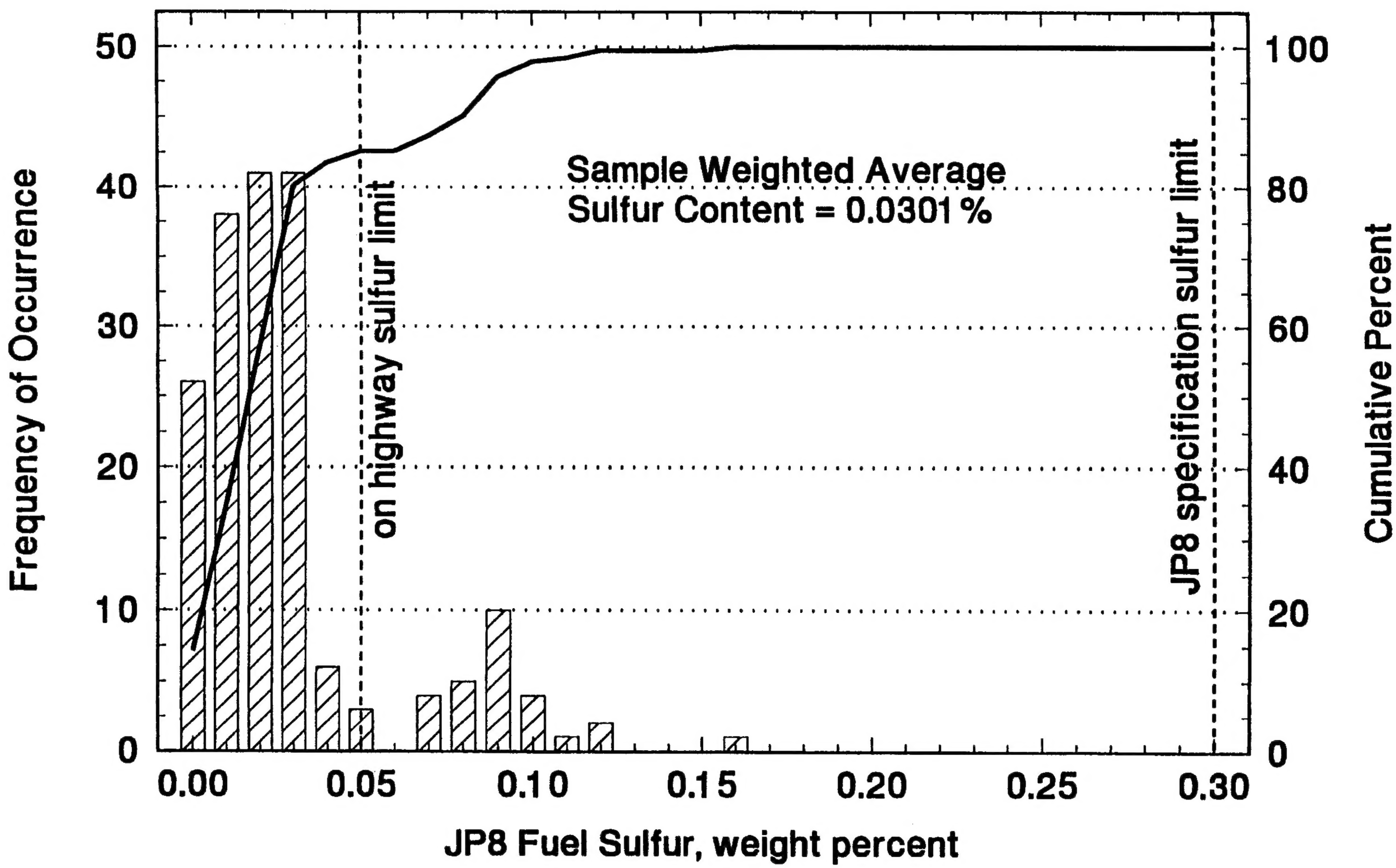


Figure 1. Fuel sulfur distribution of 182 JP-8 deliveries

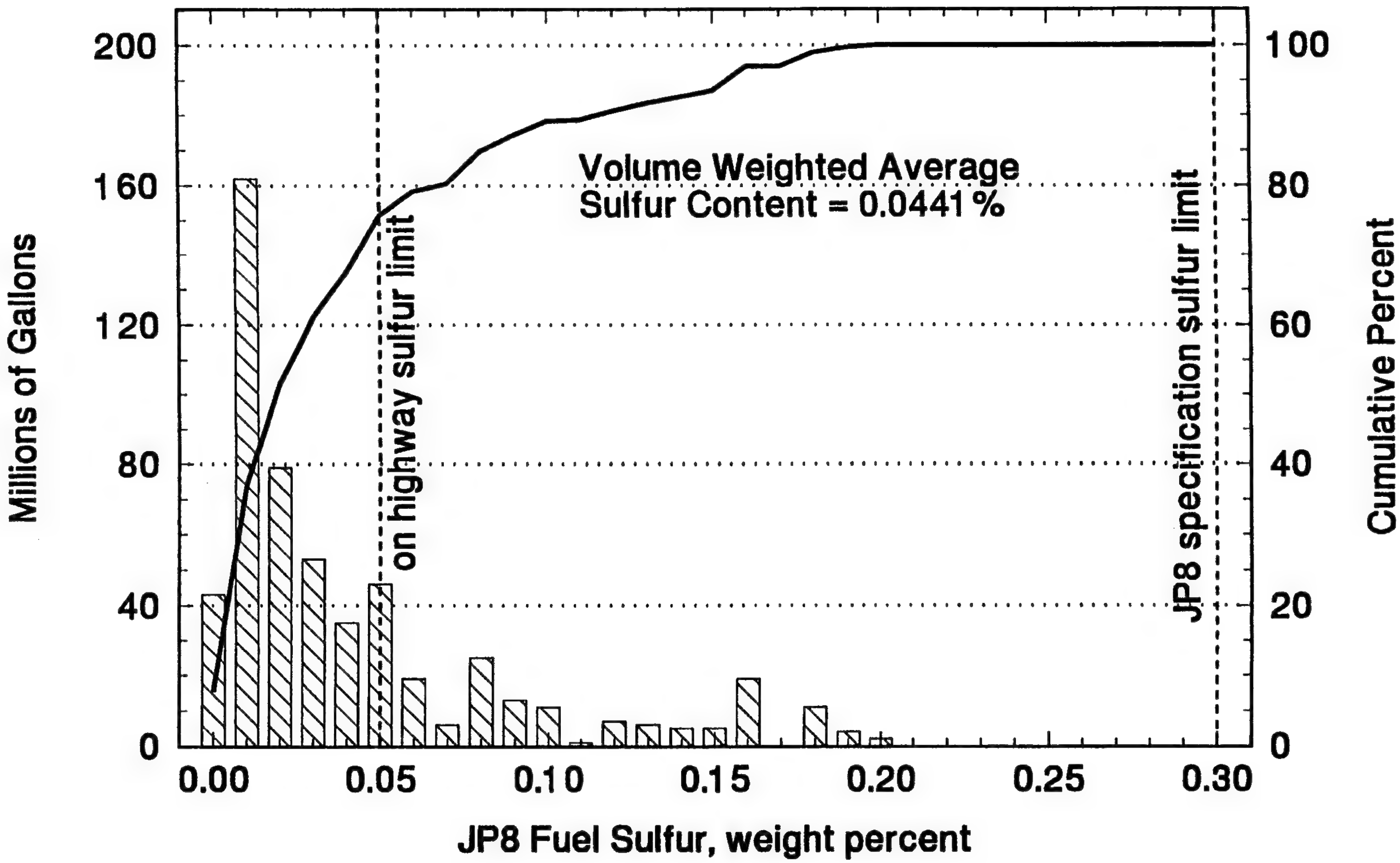


Figure 2. 1994 JP-8 fuel sulfur distribution by volume

be that required for diesel engines to meet the proposed 1994 heavy-duty diesel engine particulate emission requirements. However, the differing chemical and physical properties of kerosene and diesel fuel raise the question of the effect of fuel hydrocarbon type with respect to fuel sulfur level on diesel engine exhaust emissions. A review of available literature revealed that the effects of fuel sulfur on kerosene exhaust emissions had not been previously investigated. The intent of the Army study was to evaluate these effects in two engines: 1) a Detroit Diesel Corporation (DDC) 1991 prototype Series 60 diesel engine, a recognized fuel certification engine, and 2) a General Motors (GM) 6.2L diesel engine, representing a large portion of the Army's wheeled vehicle fleet.

II. BACKGROUND

The current EPA and California Air Resources Board (CARB) fuel formulation requirements are based in part on landmark research funded by the Coordinating Research Council (CRC).(11) The 1989–1990 CRC study evaluated the effects of diesel fuel properties on exhaust emissions in a prototype 1991 DDC Series 60 engine with respect to 1991 emission levels. The study resulted in the 1994 EPA regulation of 0.05 wt% maximum sulfur content for on-highway diesel fuel. The 1994 CARB regulation of 0.05 wt% maximum sulfur content, 10 volume percent (vol%) maximum aromatics, and 48 minimum cetane number was also established. Both the CARB and EPA maximum sulfur content requirements of 0.05 wt% are invariant. CARB allows refiners who market fuel in California to vary aromatics and cetane number to prove a substantially similar fuel to the 1994 CARB reference fuel. Currently, EPA allows CARB to define a fuel similar to the 1994 diesel fuel formulation by comparing the emission results of a CARB referee fuel with the candidate fuel recipe in a prototype 1991 DDC Series 60 engine. By definition, the candidate fuel recipe is considered similar if it produces the equivalent or lower regulated emissions as the 1994 reference fuel and does not exceed the 1991 exhaust emission levels in the prototype 1991 DDC Series 60 engine.

The EPA and CARB utilized prototype 1991 hardware in a DDC Series 60 engine to define the sulfur level for their respective 1994 low-sulfur diesel fuel specifications. Since 1990, the

prototype 1991 DDC Series 60 engine has become the EPA-, CARB-recognized standard combustion system for evaluating diesel fuel property effects on diesel engine exhaust emissions. Because of the significant contribution of diesel fuel sulfur to diesel engine exhaust particulate matter, the maximum diesel fuel sulfur specified is essential for 1994 or newer engines to meet the 1994 federal particulate emission requirements when burning diesel fuel. However, kerosene-type fuels have sufficiently differing chemical and physical properties than diesel fuel, and the fuel sulfur to particulate matter emissions correlation may not be applicable to JP-8. Therefore, kerosene-type fuels which realize equivalent or lower particulate emissions than a 1994 low-sulfur diesel reference fuel in the prototype 1991 DDC Series 60 engine would subsequently realize similar results in 1994 or newer engines. The goal for the Army is to utilize a fuel which will be capable of meeting gaseous and particulate federal diesel engine exhaust emission standards and allow the one fuel forward concept to be implemented. Thus, a procedure similar to the one EPA permits CARB to implement for certifying 1994 fuels in the prototype 1991 DDC Series 60 engine was recommended for the Army study to generate emissions data for variable sulfur JP-8 with respect to a 1994 EPA low-sulfur certification diesel fuel.

III. OBJECTIVE

The objective of this investigation was to compare the diesel exhaust emissions of kerosene-based JP-8 fuel to low-sulfur diesel fuel. The intent of the fuel emission comparisons was to show that three JP-8 fuels of varying sulfur levels would have essentially no effect on the gaseous emissions (e.g., unburned hydrocarbons, carbon monoxide, and oxides of nitrogen) but would in fact show decreases in particulate matter compared with the EPA reference fuel. The goal of the study is consistent with the fact that the EPA considers the impact of sulfur content in diesel fuel to be significant in the alteration of engine particulate matter emissions and considers fuel sulfur to have no effect on regulated gaseous emission response. Additionally, these evaluations are expected to reveal that differences in chemical and physical properties are such that the EPA correlation of fuel sulfur to diesel particulate matter emissions is not applicable to kerosene-based fuels.

IV. APPROACH

Evaluations were performed on three samples of JP-8, each with different sulfur levels, and compared to an EPA diesel certification fuel in a Southwest Research Institute (SwRI), Department of Emissions Research, 1991 prototype DDC Series 60 engine and in an Army GM 6.2L engine utilizing the hot-start transient portion of the heavy-duty diesel engine Federal Test Procedure (FTP). The JP-8 base fuel contained 0.06 wt% sulfur, which was subsequently treated with di-tertiary butyl disulfide (DTBDS) to attain 0.11 and 0.26 wt% sulfur. DTBDS is the recognized additive for adjusting fuel sulfur levels for fuels/engine research. The EPA certification diesel fuel utilized as the reference fuel for these evaluations contained 0.035 wt% sulfur. The sulfur specification range for EPA certification fuels is 0.03 to 0.05 wt%. The fuel properties for the fuels utilized in the evaluations are shown in TABLE 1.

All tests were performed utilizing the transient load command cycle as determined by the certification diesel fuel. The command cycle sets the maximum load values at a specified speed for the transient test procedure control system. This procedure ensured that all partial load points were performed at consistent brake mean effective pressures regardless of fuel type. When fuel types are switched in an engine, the vehicle operator typically extracts the engine work that will be required to satisfactorily perform a mission. This is usually done without regard for the engine fuel rack position needed to complete the task. The typical full-load torque maps for the reference diesel fuel and JP-8 fuels are shown in Fig. 3 for the 1991 Prototype DDC Series 60 engine and in Fig. 4 for the 1990 GM 6.2L engine. As expected, the full rack torque data for the three variable sulfur JP-8 fuels tested in both engines reveal little change in engine response with respect to fuel sulfur. The certification diesel fuel command cycle approach was necessary in order to account for the lower volumetric energy density and lower viscosity of JP-8, which leads to the lower peak power output with JP-8. This effectively meant the JP-8 evaluations were performed at greater partial rack settings. Using the diesel fuel command cycle, the engines' expected response to JP-8 would be a greater increase in particulate emissions than if a JP-8 command cycle was utilized.

TABLE 1. Kerosene Type JP-8 and EPA Certification 2-D Fuel Properties Utilized for Hot-Start Transient Emission Evaluations

Item	ASTM	JP-8 Analysis	EPA 2-D Analysis
Cetane Number	D 613	45.5* 46.6†‡ 49.8§	45.8
Distillation Range, °F			
Initial Boiling Point	D 86	324	361
10%	D 86	363	435
50%	D 86	399	509
90%	D 86	446	593
End Point	D 86	486	639
Density @ 15°C, kg/L	D 1298	0.8073	0.8479
Total Sulfur, mass%	D 4294	0.06* 0.11† 0.26§	0.035
Carbon, mass%	D 5291	86.08	86.75
Hydrogen, mass%	D 5291	13.76	13.00
Hydrocarbon Composition			
Aromatics, wt%	D 5186	20.5	34.3
	D 1319	--	31.4
Viscosity @ 40°C, cSt	D 445	1.32	2.71
Net Heat of Combustion			
MJ/kg	D 240	43.05	42.64
Btu/lb	D 240	18506	18331

* EM-1809-F: Neat fuel received from Kelly Air Force Base, San Antonio, TX.

† EM-1818-F: 99.86 vol% EM-1809-F + 0.14 vol% DTBDS.

‡ Not enough sample retained for cetane number analysis. Value shown is an estimate based on interpolation of data and Reference 12.

§ EM-1816-F: 99.44 vol% EM-1809-F + 0.56 vol% DTBDS.

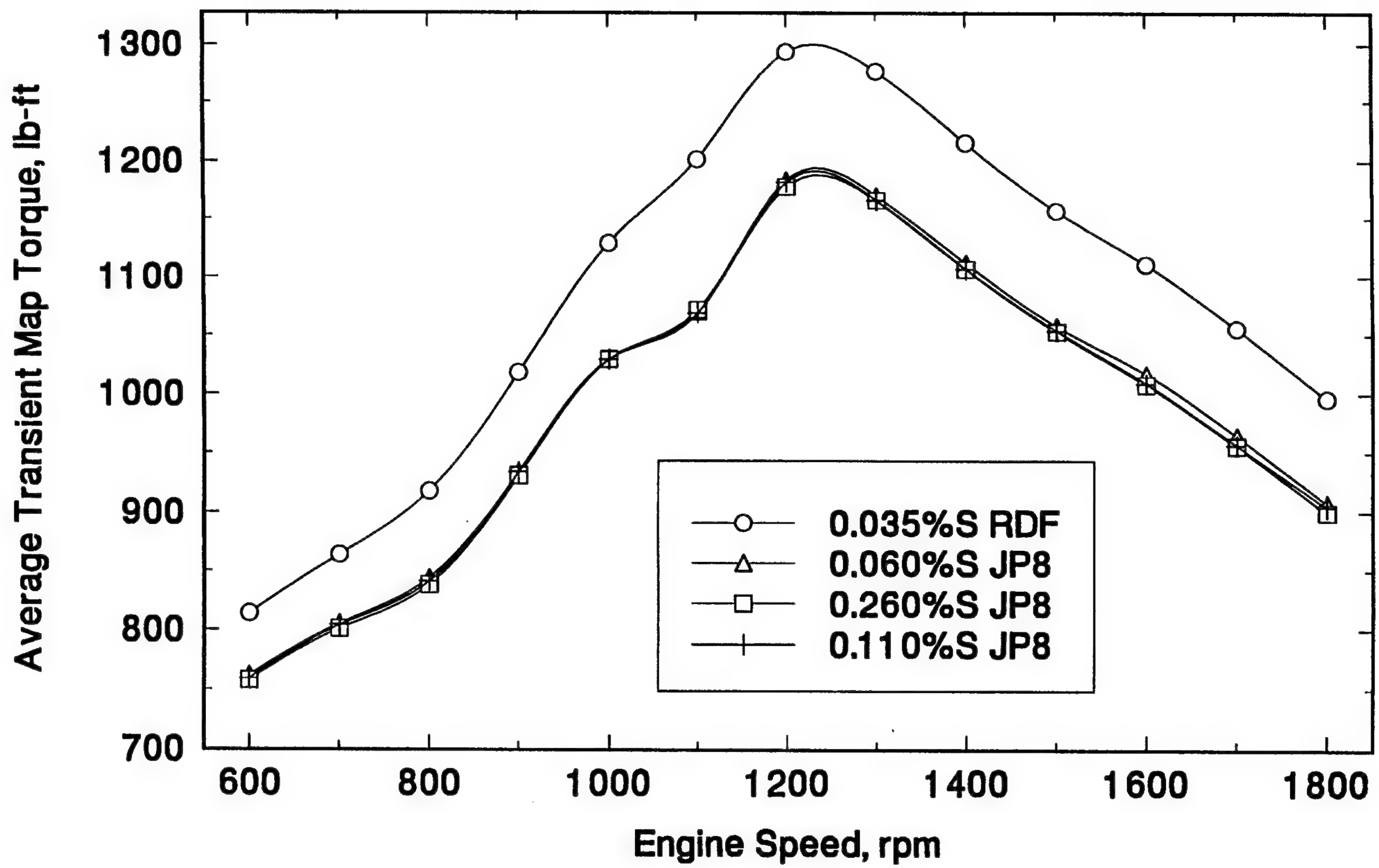


Figure 3. 1991 prototype DDC Series 60 engine transient torque maps

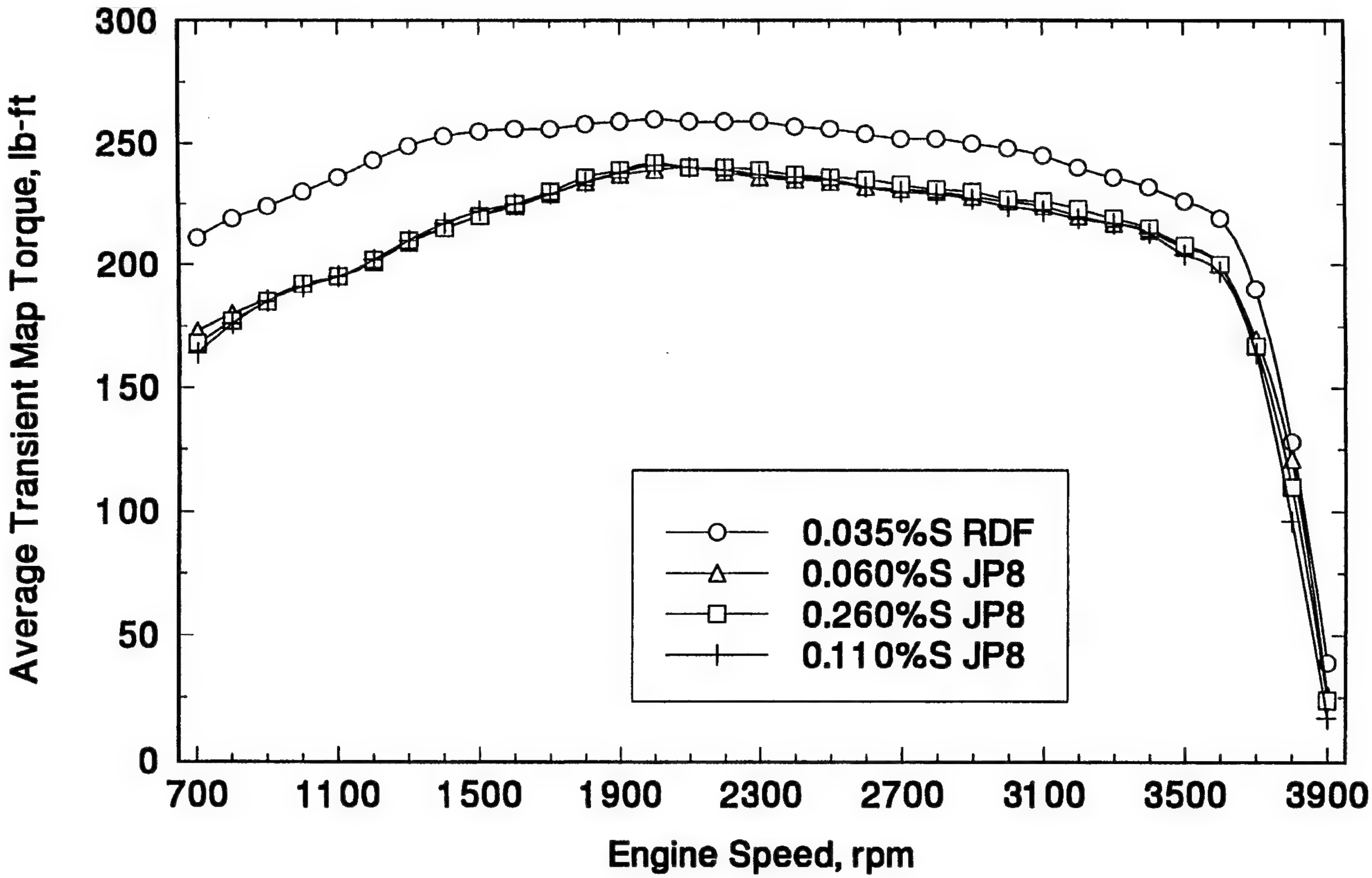


Figure 4. 1990 GM 6.2L diesel engine transient torque maps

The test sequence for the hot-start transient portion of the heavy-duty diesel engine FTP is shown in TABLE 2.

TABLE 2. Test Sequence for JP-8 Comparisons to an EPA Reference Diesel Fuel

Engine	Test Sequence	Command Cycle	Candidate Fuel
Series 60	RC_1C_1R*†	EPA 0.035% S	JP-8 (0.06% S)
Series 60	RC_1C_1R	EPA 0.035% S	JP-8 (0.06% S)
Series 60	RC_2C_2R	EPA 0.035% S	JP-8 (0.26% S)
Series 60	RC_3C_3R	EPA 0.035% S	JP-8 (0.11% S)
Series 60	RC_3C_3R	EPA 0.035% S	JP-8 (0.11% S)
GM 6.2L	RC_1C_1R	EPA 0.035% S	JP-8 (0.06% S)
GM 6.2L	RC_1C_1R	EPA 0.035% S	JP-8 (0.06% S)
GM 6.2L	RC_2C_2R	EPA 0.035% S	JP-8 (0.26% S)
GM 6.2L	RC_3C_3R	EPA 0.035% S	JP-8 (0.11% S)
GM 6.2L	RC_3C_3R	EPA 0.035% S	JP-8 (0.11% S)

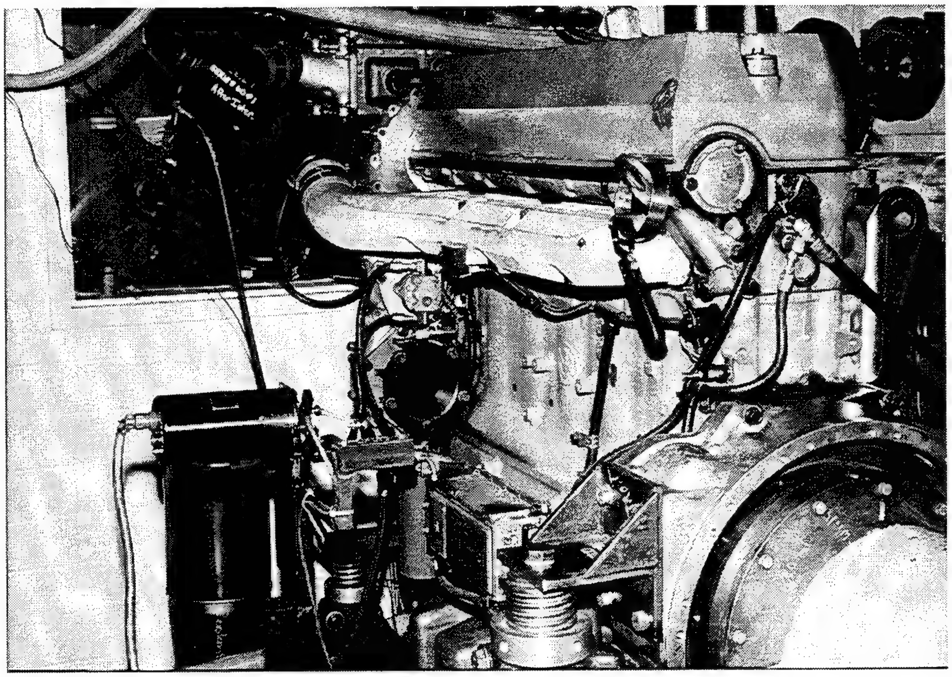
* R = Reference diesel fuel
† $C_{\#}$ = Candidate variable sulfur JP-8

V. DISCUSSION OF RESULTS

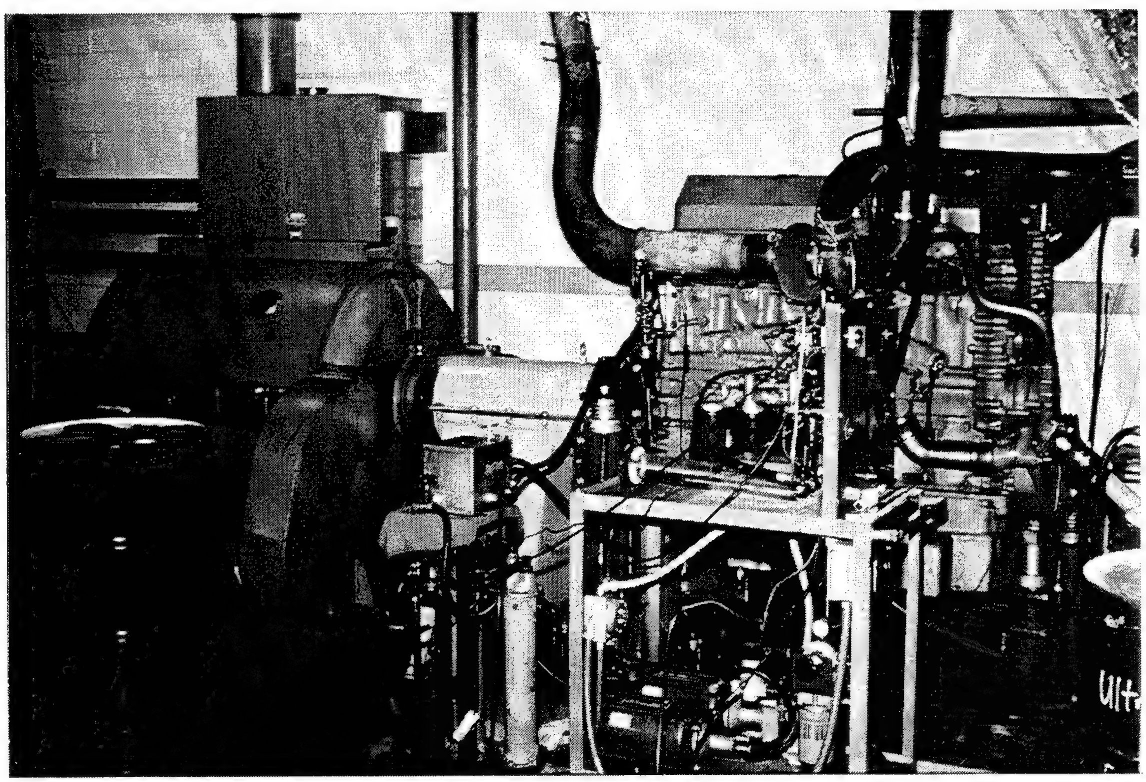
The apparent objection the EPA has for allowing the Army to consume JP-8 in their tactical wheeled vehicles is the inability to guarantee the JP-8 pool will always meet the 0.05 wt% maximum sulfur specification for on-highway diesel fuels. The predication for the EPA objection is increased particulate matter emissions caused by increased sulfur in fuels for diesel engines.

A. 1991 Prototype Detroit Diesel Corporation Series 60 Engine

Two views of the 1991 Prototype DDC Series 60 engine installed in the transient emissions test cell are shown in Fig. 5. The results for the hot-start transient regulated emissions for unburned hydrocarbons (UHC), carbon monoxide (CO), oxides of nitrogen (NO_x), and particulate matter (PM) are shown in TABLE 3 and Fig. 6 for the 1991 prototype engine. Also shown are the unregulated sulfate (SO_4) and soluble organic fraction (SOF) portion of the particulate emissions.



a. View of intake manifold side of engine from rear



b. Side view of exhaust manifold side of engine and dynomometer

Figure 5. <u>1991 prototype DDC Series 60 engine installed in transient test cell</u>

TABLE 3. Prototype 1991 DDC Series 60 Hot-Start Transient Emission Results, g/bhp-hr

Fuel	UHC	CO	NO_x	PM	SO_4	SOF
0.035% S RDF	0.5348	1.9268	4.4131	0.1697	0.0031	0.0505
0.06% S JP-8	0.5508	1.6205	4.5048	0.1320	0.0054	0.0368
0.11% S JP-8	0.6298	1.6960	4.3653	0.1533	0.0096	0.0603
0.26% S JP-8	0.5530	1.5760	4.3630	0.1765	0.0251	0.0880

The UHC emissions for all sulfur levels of the JP-8 fuels are slightly higher than the reference 0.035 wt% sulfur EPA certification fuel. Although the JP-8 fuel hydrocarbons are numerically greater than those of the EPA certification fuel, they are well within any hydrocarbon emission specification. The CO emissions for all JP-8 fuels are lower than those of the EPA certification diesel fuel. Lower CO response would indicate leaner combustion with JP-8 due to injection system losses from the lower fuel viscosity and density. With the exception of the 0.06 wt% sulfur JP-8, the NO_x response is lower than that of the EPA certification fuel. Overall, the variable sulfur JP-8 fuels do not grossly impact the regulated gaseous emission response of the Series 60 engine. A detailed statistical analysis of the emission data (found in the Appendix) supports the aforementioned conclusion.

Fuel properties that can influence particulate matter emissions include fuel density, volatility, cetane number, sulfur, and aromatic content.(13) The JP-8 fuels evaluated had higher volatility, lower fuel density, and lower aromatic content than the EPA certification fuel, all properties beneficial for producing a lower particulate emission response. The addition of the DTBDS to vary fuel sulfur had two effects: 1) an increase in fuel sulfur, and 2) an increase in cetane number.(12) An increase in fuel sulfur tends to increase particulate matter emissions, while an increase in cetane number tends to lower particulate matter emissions.

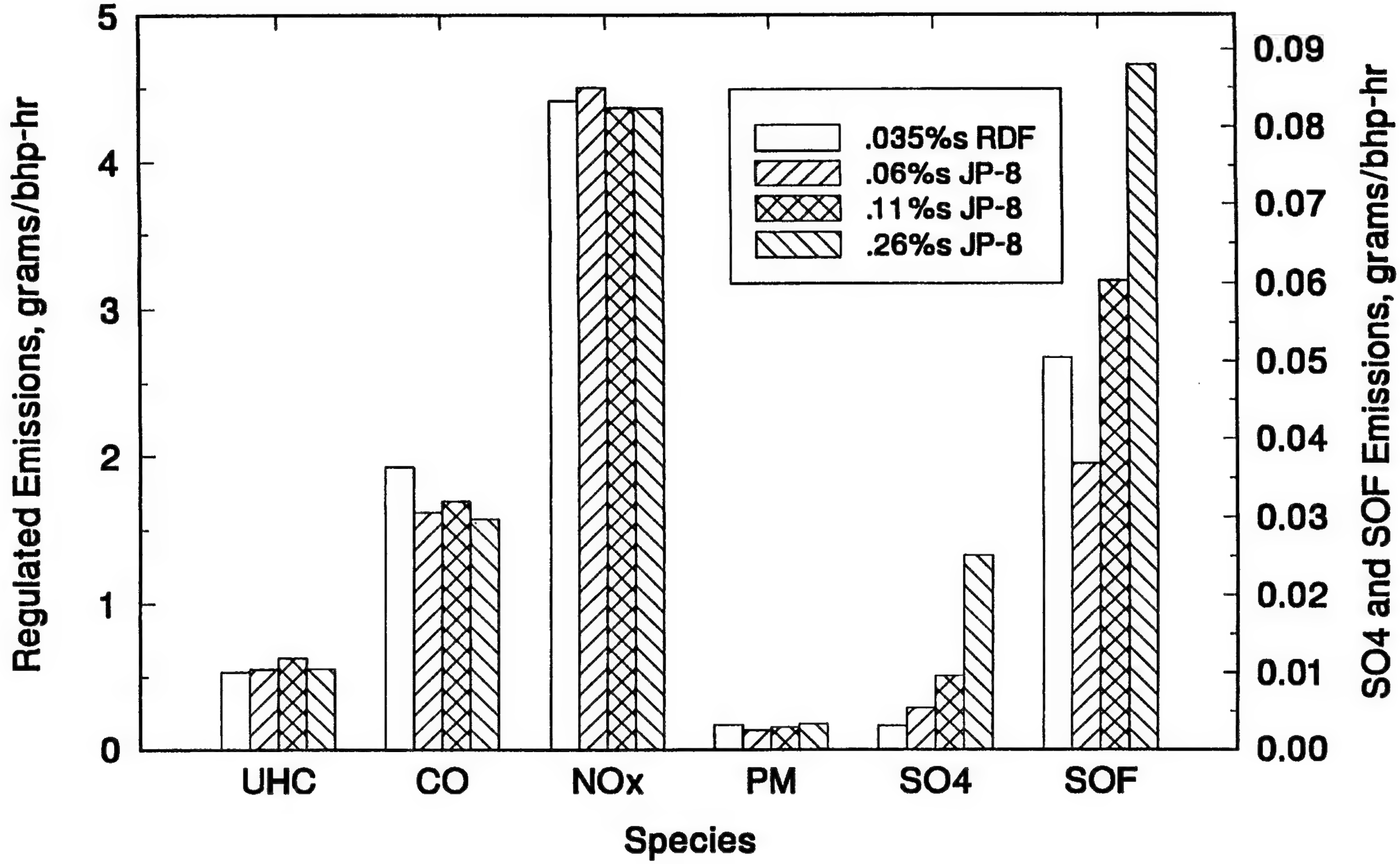


Figure 6. Hot-start transient averaged emission results for the 1991 prototype DDC Series 60 engine

The particulate matter emission data indicate the 0.06 and 0.11 wt% sulfur JP-8 fuels have lower particulate emissions than the 0.035 wt% sulfur EPA certification fuel even though both JP-8 fuels exceed the maximum 0.05 wt% sulfur EPA requirement for on-highway fuels. The 0.26 wt% percent sulfur JP-8 did reveal slightly greater particulate matter emissions than the EPA certification fuel. Figure 7 presents particulate matter data from this study along with data generated by SwRI (14) on a 0.007 wt% sulfur JP-8. The JP-8 emission data from Reference 14 was measured utilizing a command cycle that was generated using a California specification reference fuel. The California reference fuel produced a full rack response similar to the EPA certification fuel in the Series 60 engine; thus, the JP-8 particulate matter data from Reference 14 is included in the least squares fit of the Series 60 engine response to kerosene fuel sulfur. Based on a linear interpolation ($R^2 = 0.95$) of the particulate matter data, the equivalent sulfur level JP-8 for the 1991 Prototype DDC Series 60 engine is approximately 0.21 wt% sulfur in order to achieve the corresponding particulate matter emission level as the reference 0.035 wt% sulfur EPA certification diesel fuel.

A brief review of the sulfate portion of the particulate emissions validates the reasonable assumption that sulfate emissions increase with fuel sulfur content. The SOF portion of the particulate appears to increase with fuel sulfur levels. However, the base 0.06 wt% sulfur JP-8 SOF emissions were less than that of the 0.035 wt% sulfur EPA certification fuel. This would indicate fuel properties other than fuel sulfur also contribute to the SOF portion of the particulate.

B. 1990 General Motors 6.2L Engine

A 1990 GM 6.2L engine was purchased from the military supply system as the engine was no longer commercially available. After completing a factory specified run-in, the GM 6.2L engine underwent a 125-hour service accumulation, as specified by the FTP, utilizing a load cycle supplied by General Motors Powertrain. The purpose of the service accumulation was to stabilize the oil consumption of the engine because of the impacts of oil consumption on exhaust emissions. The engine was then installed in a transient emission test cell for the hot-start transient emission evaluations.

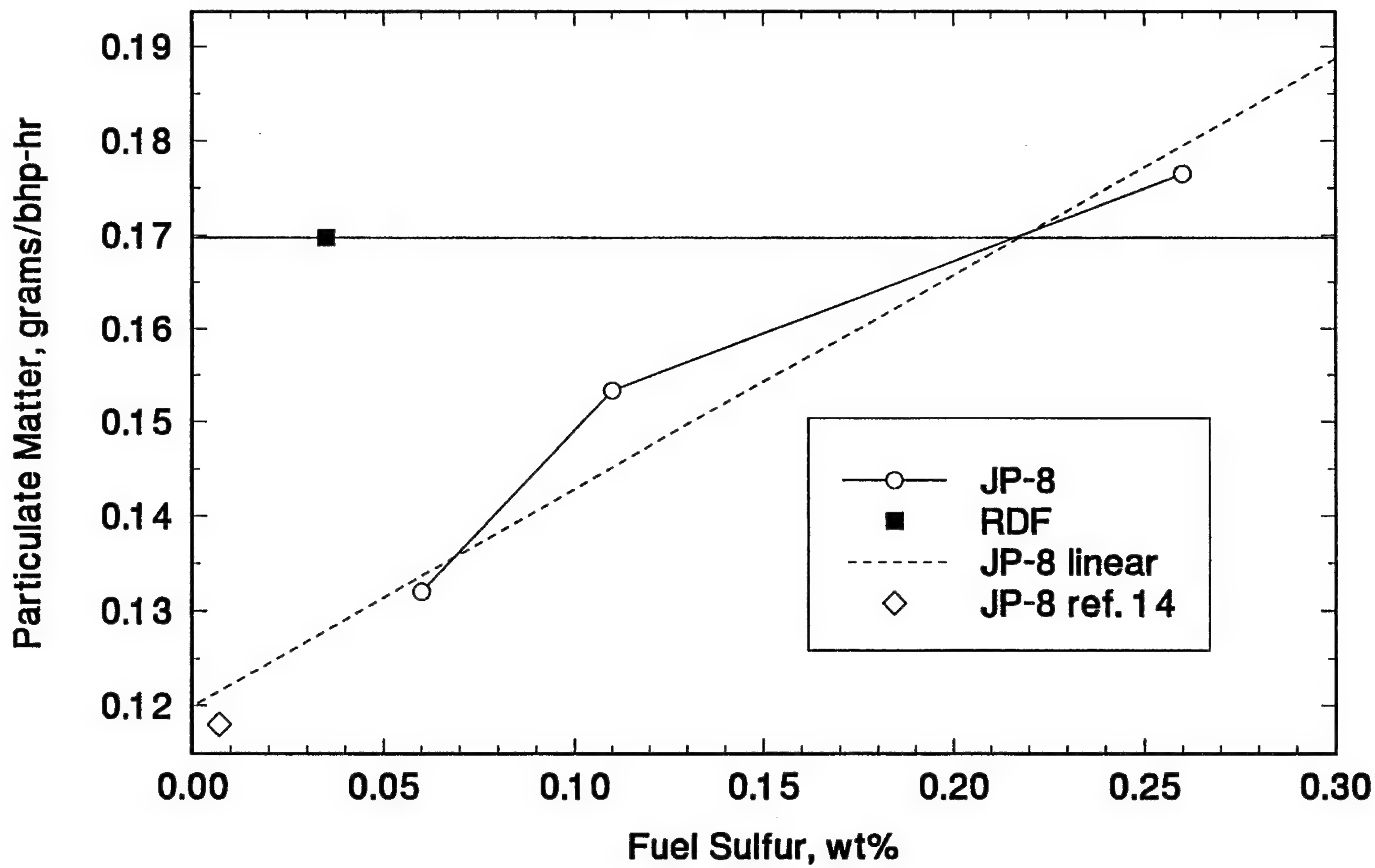
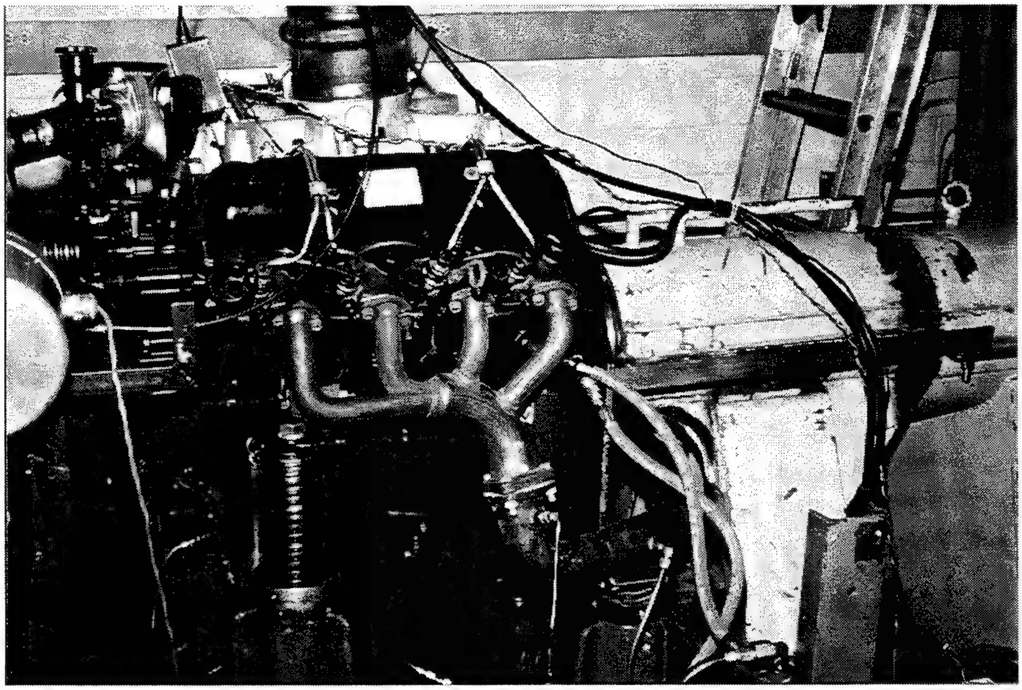


Figure 7. Particulate matter emissions for the 1991 prototype DDC Series 60 engine

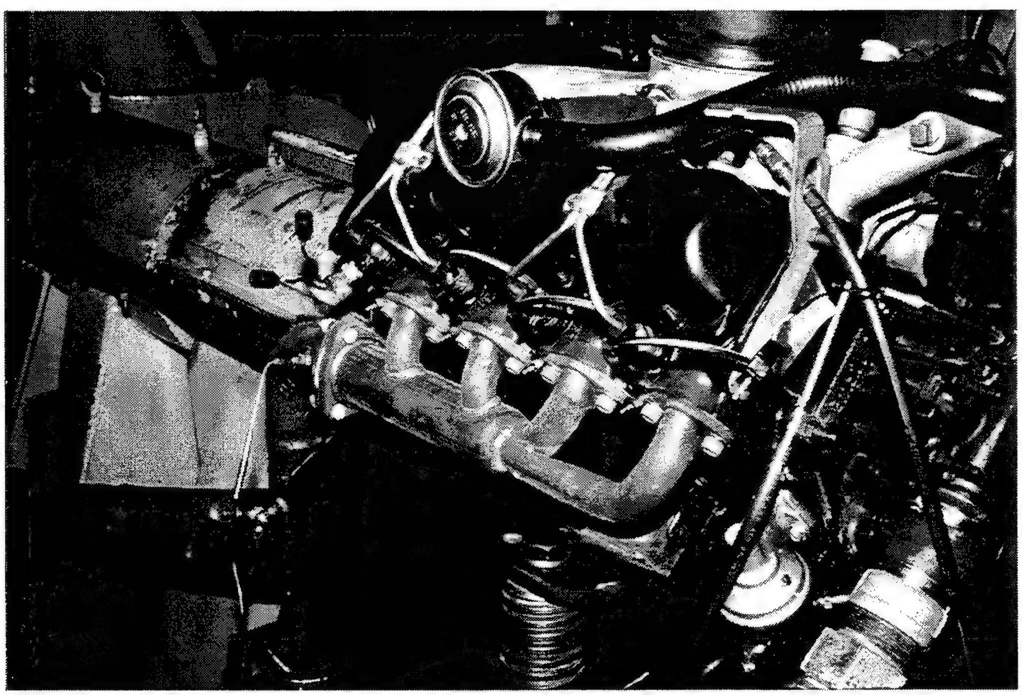
Two views of the 1990 GM 6.2L engine installed in the transient emissions test cell are shown in Fig. 8. The results for the hot-start transient regulated emissions for UHC, CO, NO_x, and PM are shown in TABLE 4 and Fig. 9 for the 1990 GM 6.2L engine. Also shown are the SO_4 and SOF portions of the particulate emissions.

The data for the regulated emissions for UHC, CO, and NO_x indicated the 1990 GM 6.2L engine had a mixed response with the JP-8 fuels with respect to the reference 0.035 wt% sulfur EPA certification fuel. The UHC and CO gaseous emission responses for the 0.06 wt% sulfur JP-8 were high compared to the other fuels. A lower NO_x response for the 0.06 wt% sulfur JP-8 is consistent with the trend expected for higher UHC and CO responses. Further analysis of the hydrocarbon data reveals an instability in the engine hydrocarbon response. The numbers over the bars in Fig. 10 denote the run order for all fuel evaluations, and the hydrocarbon response appears more consistent with the later evaluations. This would tend to indicate that the engine had insufficient hours accumulated to attain an emission balance, and it could be theorized that the engine oil consumption had not yet stabilized. The two other high-sulfur JP-8 fuels revealed lower UHC, CO, and NO_x emissions than the reference 0.035 wt% sulfur EPA certification fuel. Overall, the variable sulfur JP-8 fuels do not grossly impact the regulated gaseous emissions response of the GM 6.2L engine. A detailed analysis of the results is available in the Appendix.

The GM 6.2L engine revealed lower particulate matter emissions than the reference 0.035 wt% sulfur EPA certification fuel with all JP-8 sulfur levels, even though all JP-8 sulfur levels exceeded the maximum 0.05 wt% sulfur EPA low-sulfur fuel specification. Of note is the 0.06 wt% sulfur JP-8 (the first JP-8 fuel evaluated after the service accumulation), which shows a slightly greater particulate response than the 0.11 wt% sulfur JP-8 that was evaluated last. It is possible that this greater particulate response could be caused by increased oil consumption due to insufficient service accumulation. A linear extrapolation ($R^2 = 0.94$) of the particulate matter data shown in Fig. 11 indicates all sulfur levels of JP-8, up to the 0.30 wt% MIL-T-83133 specification maximum, would result in lower particulate matter emission levels than the reference 0.035 wt% sulfur EPA certification fuel in the 1990 GM 6.2L engine.



a. View of right side of engine



b. View of left side of engine at close range

Figure 8. <u>1990 GM 6.2L engine installed in transient test cell</u>

TABLE 4. 1990 GM 6.2L Engine Hot-Start Transient Averaged Emission Results, g/bhp-hr

Fuel	UHC	CO	NO_x	PM	SO_4	SOF
0.035% S RDF	0.4540	1.8222	3.2519	0.2905	0.0028	0.0930
0.06% S JP-8	0.6398	2.1150	3.2168	0.2288	0.0041	0.0925
0.11% S JP-8	0.4363	1.7718	3.2420	0.2283	0.0096	0.0823
0.26% S JP-8	0.4115	1.7545	3.2400	0.2715	0.0217	0.1145

A review of the sulfate portion of the particulate emissions confirms the reasonable assumption that sulfate emissions increase with fuel sulfur content. The SOF portion of the particulate appears to increase with fuel sulfur levels; however, the 0.06 and 0.11 wt% sulfur JP-8 SOF emissions were less than that of the 0.035 wt% sulfur EPA certification fuel. The 0.11 wt% sulfur JP-8 had a lower SOF response than the base 0.06 wt% sulfur JP-8, which would indicate factors other than fuel properties also contributed to the SOF portion of the particulate. Another known major contributor to the SOF portion of the particulate is the lubricating oil consumed by the engine. Figure 12 presents the SOF emissions for the individual fuel evaluations, which display a variability in the SOF response. This tends to lend credence to the supposition that the GM 6.2L engine lubricant consumption had not stabilized during the service accumulation, thereby affecting the results of the base 0.06 wt% sulfur JP-8. Excess engine lubricating oil consumption would lead to an increased amount of lower volatility and higher density material in the cylinder, resulting in increased UHC, increased PM, and subsequently increased SOF portion of the particulate.

C. Direct Injection vs. Indirect Injection

The 1991 Prototype DDC Series 60 engine utilizes an open chamber, direct injection combustion system calibrated to provide a low NO_x response while meeting the 1991 heavy-duty diesel engine particulate specification. The 1990 GM 6.2L diesel engine utilizes a pre-chamber, indirect injection combustion system calibrated to meet the 1990 heavy-duty diesel engine particulate specification. A table of engine characteristics is available in the Appendix. The federal NO_x

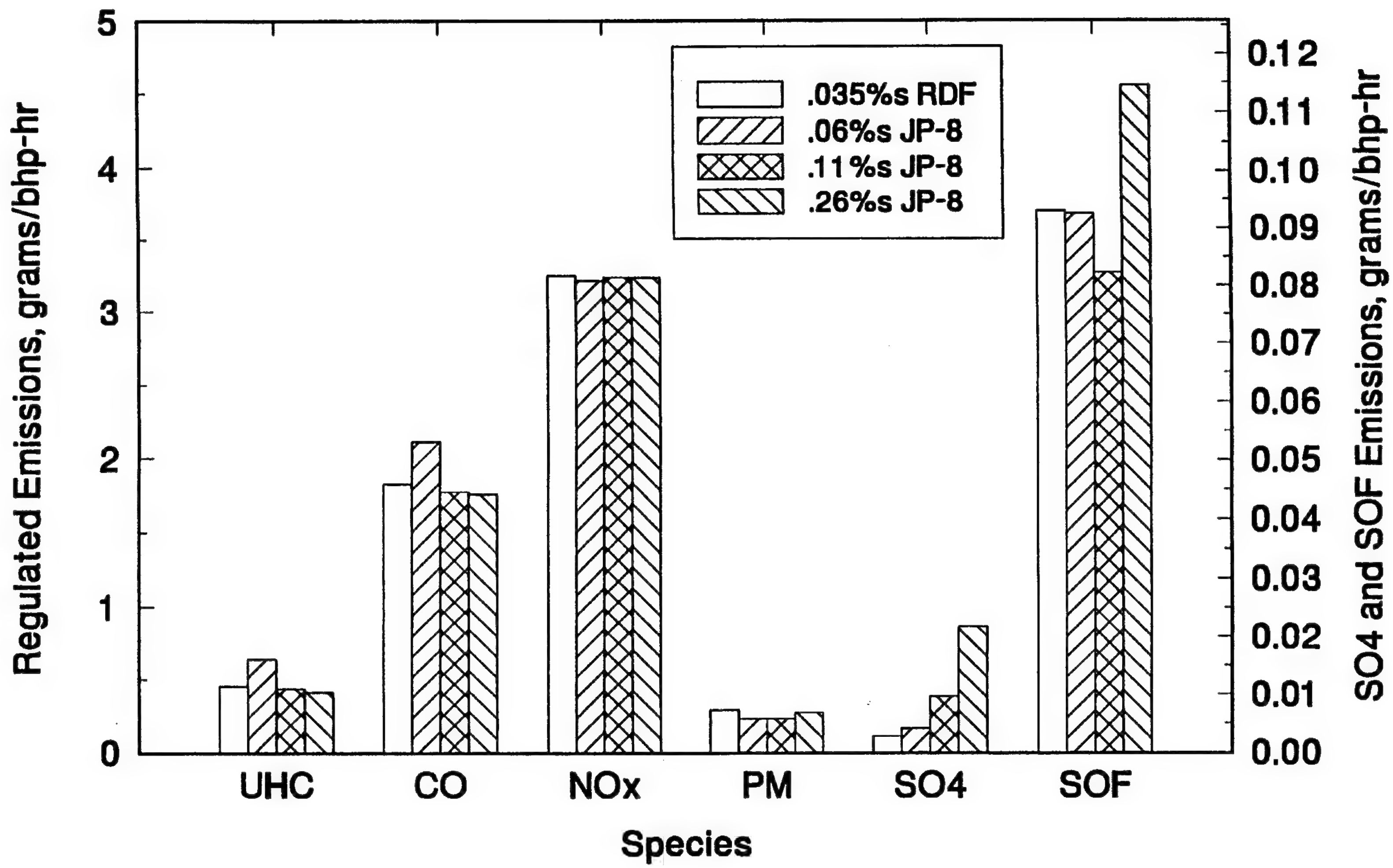


Figure 9. Hot-start transient averaged emission results for the 1990 GM 6.2L diesel engine

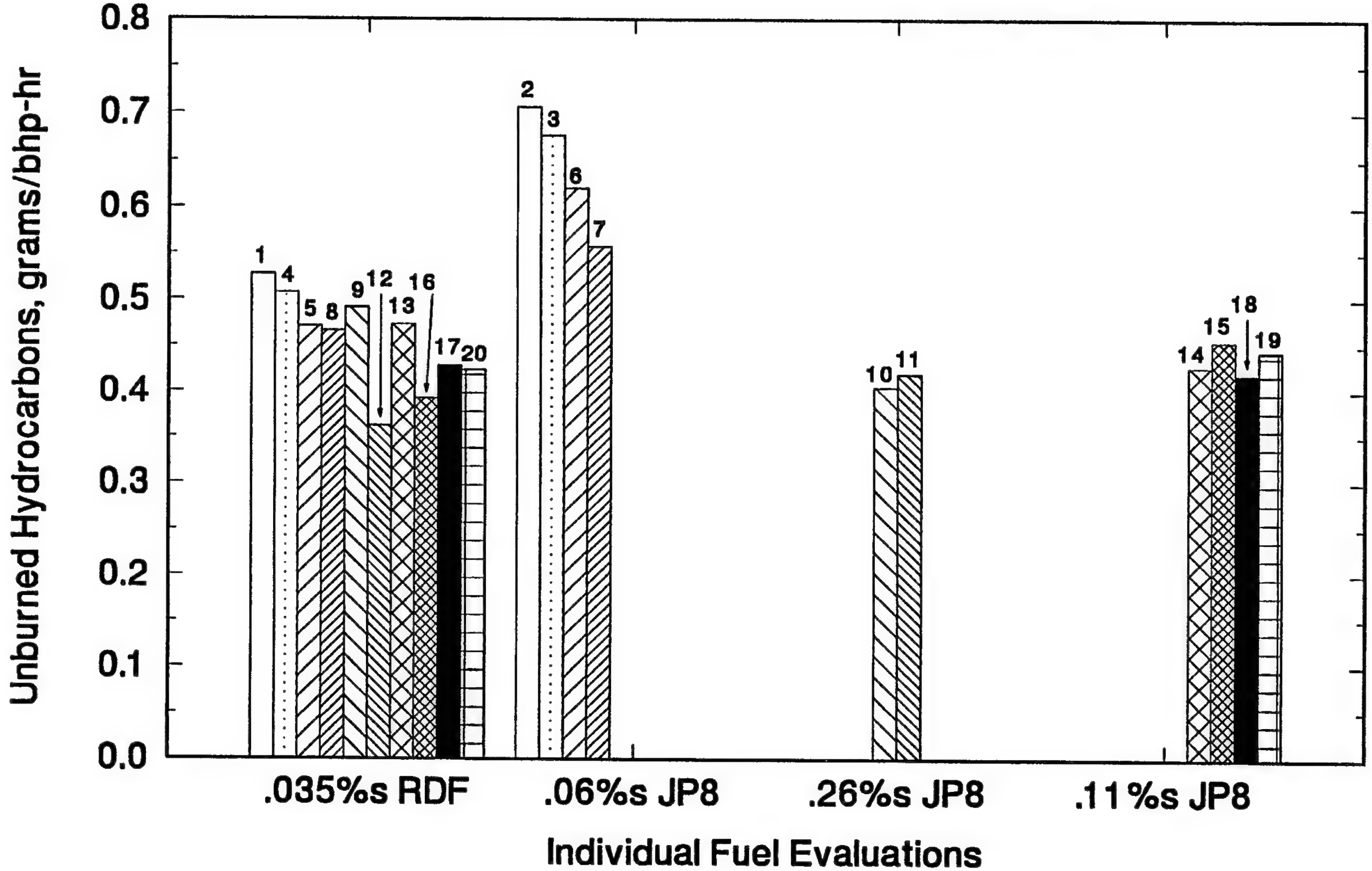


Figure 10. Hydrocarbon emission stability results for the 1990 GM 6.2L engine

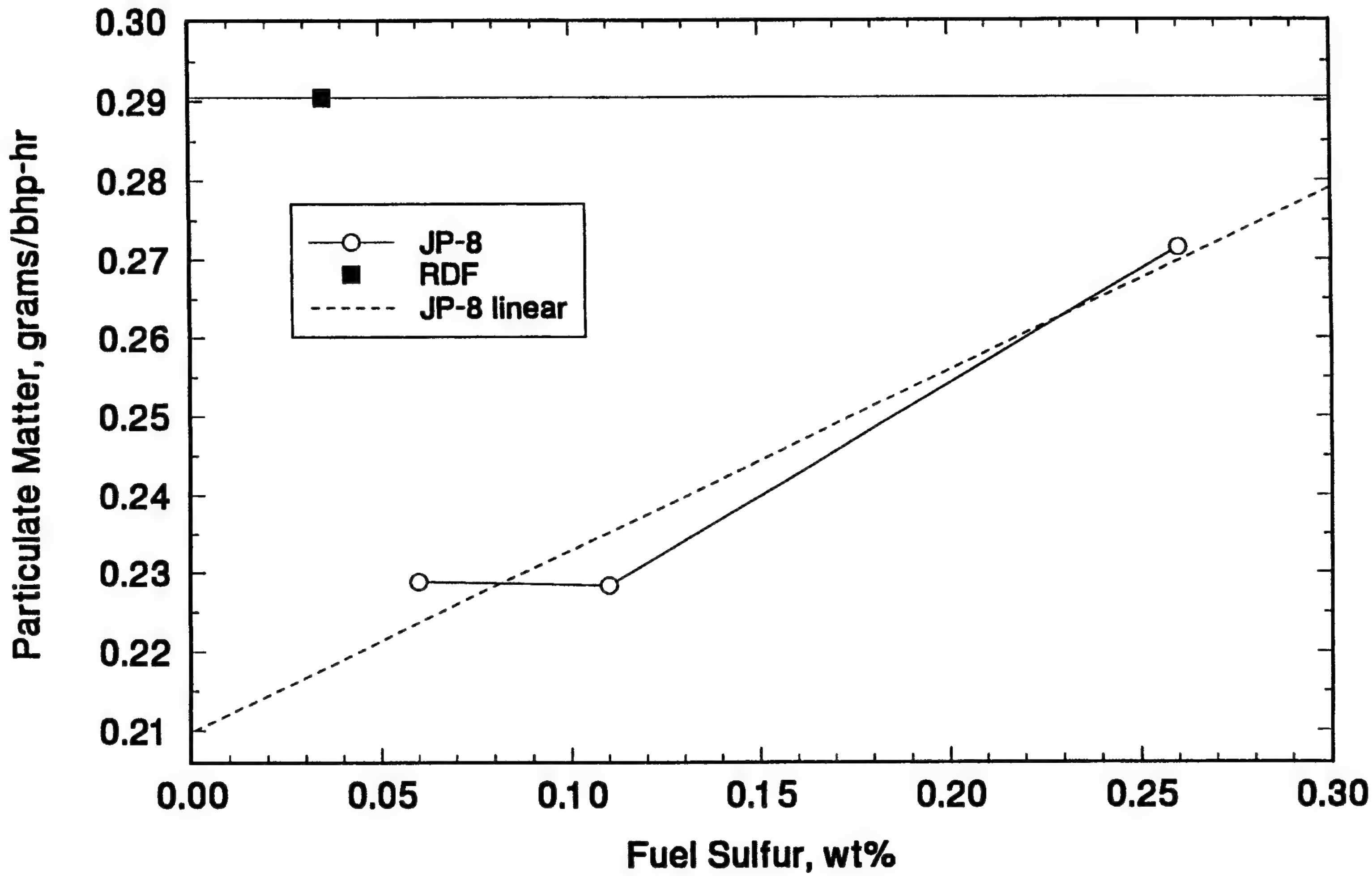


Figure 11. Particulate matter emissions for the 1990 GM 6.2L engine

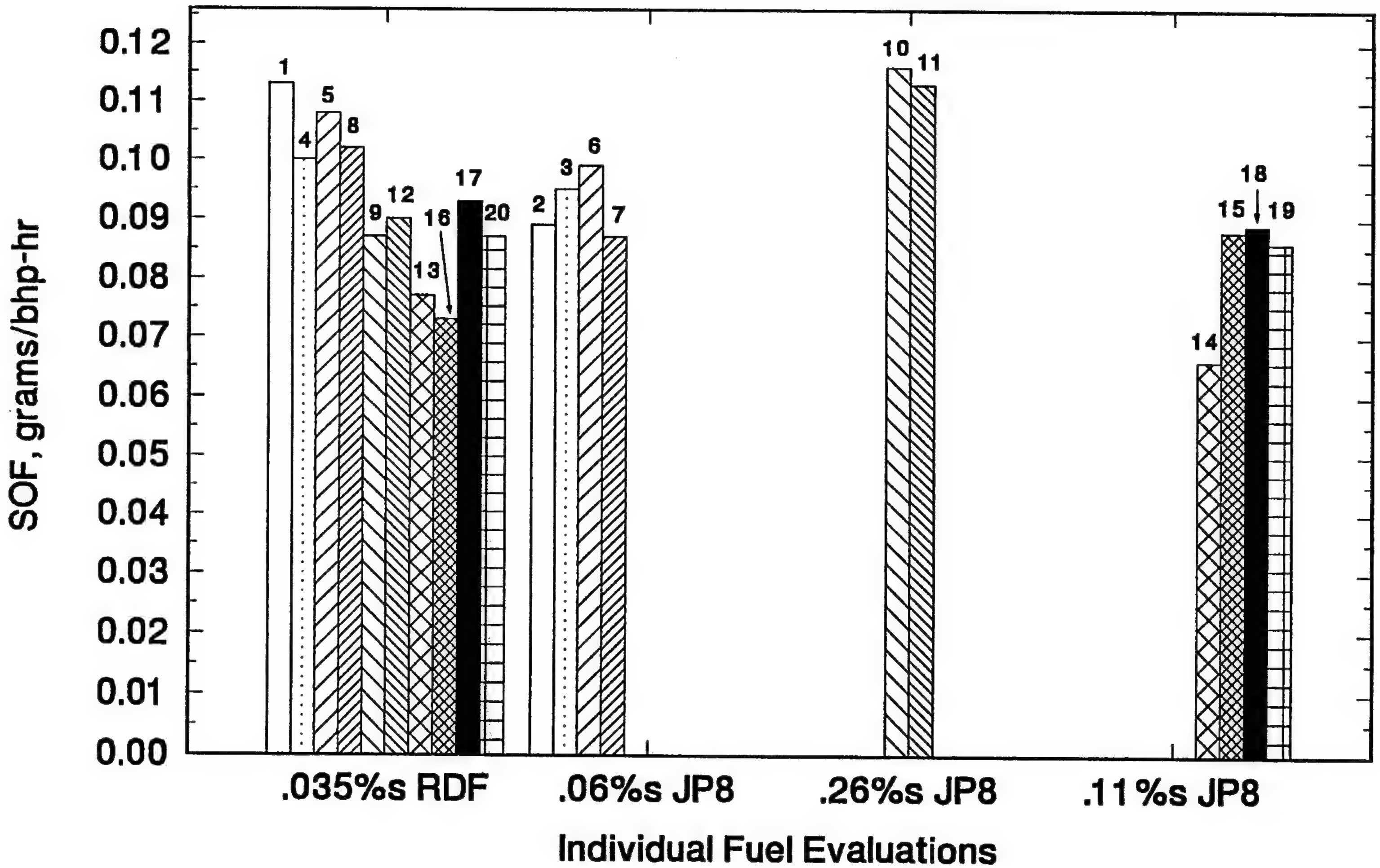


Figure 12. <u>Particulate SOF emission results for the 1990 GM 6.2L engine</u>

specifications for 1990 and 1991 were 6.0 and 5.0 g/bhp-hr, respectively, while the particulate specifications for 1990 and 1991 were 0.6 and 0.25 g/bhp-hr, respectively. The UHC and CO specifications went unchanged for 1990 and 1991 at 1.3 g/bhp-hr and 15.5 g/bhp-hr, respectively. A comparison of the regulated gaseous and particulate emissions plus the sulfate and SOF for the DDC Series 60 engine and the GM 6.2L engine is shown in Fig. 13. Overall, the GM 6.2L engine reveals slightly lower UHC response and significantly lower NO_x emissions than the DDC Series 60. The lower UHC may be attributed to better air utilization and mixing inherent in a pre-chamber engine like the GM 6.2L engine. The lower NO_x response is most likely a result of the increased heat transfer in a pre-chamber engine due to higher surface-to-volume ratio and increased film coefficient due to increased swirl velocities, which contrive to reduce the peak combustion temperature and reduce NO_x formation. Likewise, the slightly increased CO response with the pre-chamber GM 6.2L engine may be the result of increased heat transfer and surface area, which can quench combustion, thereby increasing CO. The increased SOF of the GM 6.2L over the DDC Series 60 is most likely due to the particulate calibration and the lubricating oil consumption characteristics of the engines.

VI. SUMMARY

The EPA considers the impact of sulfur content in diesel fuel to be significant in the alteration of particulate matter emissions of an engine but is considered to have no effect on gaseous emission response.(15) The EPA requirement of 0.05 wt% maximum sulfur for on-highway diesel fuels is the defined sulfur level that 1994 diesel engines must meet to satisfy the 1994 particulate emission specification. The comparisons of <u>kerosene</u> fuels with sulfur contents greater than 0.05 wt% in two distinctly different engines utilizing the hot-start transient portion of the FTP for heavy-duty diesel engines has produced the following results:

- A 1991 Prototype DDC Series 60 engine particulate matter response reveals that an approximate sulfur level of 0.21 wt% in <u>kerosene</u> type JP-8 would be equivalent to a 0.035 wt% sulfur EPA certification diesel fuel.

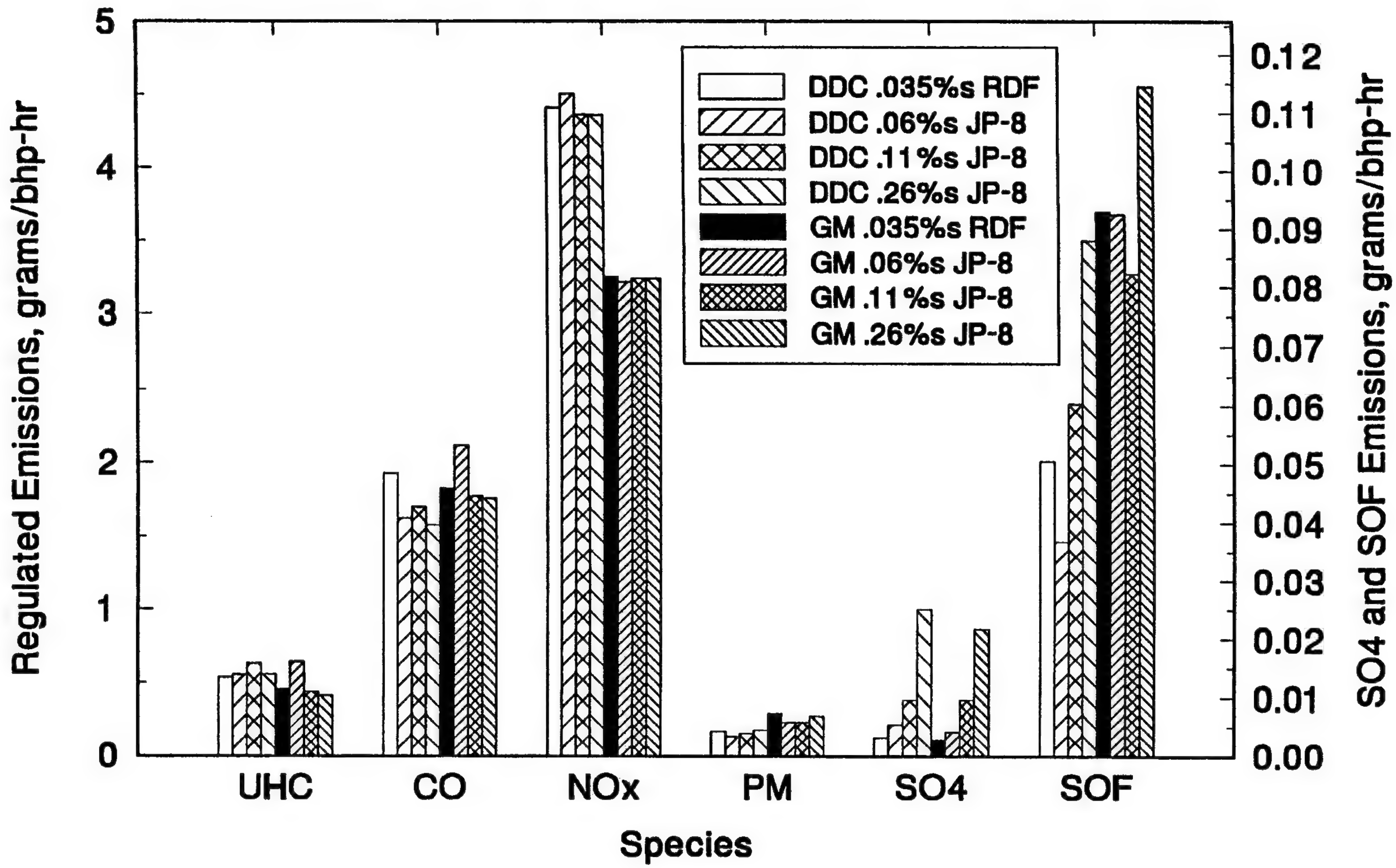


Figure 13. A comparison of the hot-start transient averaged emission results for the DDC direct injection and the GM indirect injection engines

- A 1990 GM 6.2L engine particulate matter response reveals that all sulfur levels of kerosene type JP-8, up to the 0.30 wt% MIL-T-83133 specification maximum, would be equivalent to a 0.035 wt% sulfur EPA certification diesel fuel.

- The gaseous and particulate emission data from the 1991 Prototype DDC Series 60 engine and the 1990 GM 6.2L engine indicate both engines would meet their respective model year gaseous and particulate emission requirements with all sulfur levels of kerosene type JP-8.

The particulate emission data suggest kerosene-based JP-8 fuels have sufficiently different chemical and physical properties than distillate-based fuels such that the correlation of fuel sulfur with respect to particulate for distillate type diesel fuels cannot be applied directly to kerosene type fuels for on-highway use.

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APPENDIX

Southwest Research Institute
Department of Emissions Research
Engine Operating and Emission Data
and Statistical Data Analysis

SwRI 02-5137-506

TRANSIENT EMISSIONS TESTING OF VARIABLE SULFUR IN JP-8

By

Daniel A. Montalvo

FINAL REPORT

Prepared for

FUELS AND LUBRICANTS DIVISION
Mobility Technology Center Belvoir
5941 Wilson Road, Suite 230
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March 1995

SOUTHWEST RESEARCH INSTITUTE

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WASHINGTON, DC

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SUMMARY

The objective of this study was to determine the effect of varying JP-8 sulfur content on total particulate matter (PM), HC, CO, NO_x, sulfate, and SOF emissions from both a prototype 1991 DDC Series 60 heavy-duty diesel engine and a 1990 GM 6.2L heavy-duty diesel engine operated over the EPA Federal Test Procedure (FTP) transient cycle. Hot-start transient emission results were accumulated on reference fuel (Fuel 2D, a low sulfur, No. 2 grade diesel fuel), along with three JP-8 fuels (Fuels C1, C2, and C3), containing various levels of sulfur. Sulfur contents of Fuels C1, C2, and C3 were 0.06, 0.26, and 0.11 weight percent, respectively. Corresponding cetane number of Fuel 2D and of Fuels C1, C2, and C3 candidate fuels were 45.8 and 45.5, respectively. Aromatic content of Fuel 2D was 31.4 weight percent, and for Fuels C1, C2, and C3, it was 20.5 weight percent.

Torque differences between Fuels C1, C2, and C3 on both engines were minor and were generally within test-to-test repeatability observed when using the same fuel. However, average reductions in torque of 9 and 12 percent were obtained with the JP-8 fuels as compared to Fuel 2D using the Series 60 and GM 6.2L engines, respectively.

A selected statistical method was applied to the test data to examine the hypothesis that the population mean value for an emission of a given pollutant on one fuel did not differ from the population mean value for emission of that pollutant on the other fuel, essentially saying that emission of the selected pollutant for the two fuels was not different. Because the test data did not meet all of the strict requirements of the statistical method, the results obtained were applied only for summarization purposes. Accepting or rejecting the hypothesis is always subject to change with further testing.

For this report, the hypothesis was accepted or rejected on the basis of a 5 percent significance level (a 95 percent confidence level), determined using a two-sided Student "t" statistic. Use of a different significance level, random sampling, or a larger sample size could result in a different conclusion. The statistical conclusions from testing the hypothesis indicated whether the respective emission levels for Fuel R and for Fuels 2D, C1, C2, and C3 were either **Equal (Fuel C is equal to Fuel R)** or **Not Equal (Fuel C is either lower or higher than Fuel R)**. These "conclusions" are summarized in the table below, and they are arranged by engine and JP-8 sulfur level.

STATISTICAL CONCLUSIONS TO THE HYPOTHESIS THAT EMISSION OF A POLLUTANT FOR FUEL C EQUALS THAT FOR FUEL R

Test Fuel ID	Fuel Sulfur, Wt. %	Statistical Conclusion to the Hypothesis[a]					
		HC	CO	NO_x	PM	Sulfate	SOF
1991 Prototype DDC Series 60 Engine							
C1	0.06	C = R	C<R	C = R	C<R	C>R	C<R
C3	0.11	C>R	C<R	C<R	C<R	C>R	C = R
C2	0.26	C>R	C<R	C<R	C>R	C>R	C>R
1990 GM 6.2L Engine							
C1	0.06	C>R	C>R	C = R	C<R	C>R	C<R
C3	0.11	C = R	C = R	C = R	C<R	C>R	C = R
C2	0.26	C = R	C = R	C = R	C = R	C>R	C>R

[a]This conclusion indicates that there is no distinction between the emission level for candidate Fuel C relative to the emission level for reference Fuel R. If C does not equal R, then there is a significant difference between emissions on the two fuels.

For both engines, HC emission levels on JP-8 fuels tended to be the same or greater than the levels noted with 2D. No trend for HC emissions with increased sulfur content was noted. On the Series 60, CO emission levels were always lower with JP-8 than with 2D, whereas for the GM 6.2L, CO emission levels with JP-8 were somewhat higher or equal to levels obtained with 2D. No trend for CO emissions with increased sulfur content was noted. Although NO_x emission levels for the Series 60 were statistically lower with two JP-8 fuels (C2-C3), Series 60 NO_x emissions on all the JP-8 fuels and 2D fuel were essentially the same. Similarly, no difference in emissions of NO_x were attributed to differences in sulfur content among the three JP-8 fuels.

For background, total particulate emissions from diesel engines are affected by various fuel properties such as density, cetane number, sulfur, and others. Likewise the characteristics of the total particulate (sulfate and SOF) are also affected. Generally, for most diesel engines, as density of the fuel is reduced, total particulate emissions are reduced. Also, as sulfur is increased the sulfate portion of total particulate generally increases. SOF can also increase, because sulfate collected as part of the total particulate on a filter tends to increase the level of soluble material collected on the filter.

With this background information, sulfate levels for all three JP-8 fuels on both engines were greater than for the 2-D fuel, which had the lowest fuel sulfur content. As JP-8 fuel sulfur content increased, sulfate emissions were increased for both engines. Also for both engines, SOF emissions were lower with the low density JP-8 with relatively low sulfur content (C1) than with 2-D. As the sulfur content (C1 to C3 to C2) of JP-8 was increased from 0.06 to 0.11 to 0.26 weight percent, SOF increased to levels exceeding the levels measured for 2-D on both engines.

Total particulate emission levels (containing both sulfate and SOF) for both engines were lower with the low sulfur JP-8 (C1) than with 2-D. However, as the sulfur content of the JP-8 was increased, increased sulfate and SOF emissions contributed to increased total particulate such that for both the Series 60 and the GM 6.2, total particulate levels on the highest sulfur JP-8 fuel (C2) were greater than or equal to the level of total particulate obtained on the more dense 2-D fuel.

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I. INTRODUCTION AND PROJECT OVERVIEW

The test results reported herein were generated by the Department of Emissions Research (DER), Automotive Products and Emissions Research Division of Southwest Research Institute, for the U.S. Army. This study was identified as "Transient Emissions Testing of Variable Sulfur in JP-8," run on SwRI Project 02-5137-506, conducted under SwRI Contract DAAK 70-92-C-0059, and managed by the U.S. Army Belvoir Fuels and Lubricants Research Facility (BFLRF) at SwRI. The BFLRF Project Leader was Mr. Doug Yost. Mr. Daniel A. Montalvo was the DER Project Leader and Mr. Terry L. Ullman was the Project Manager.

The objective of this study was to determine the effect of varying JP-8 sulfur content on total particulate matter (PM), HC, CO, NO_x, sulfate, and the soluble organic fraction of the total particulate (SOF) using two heavy-duty diesel engines operated over the transient cycle specified by the EPA. Hot-start transient emission results were obtained on reference fuel 2D, a low sulfur, No. 2 grade diesel fuel. In addition, emission tests were also run on three JP-8 fuels containing various levels of sulfur. These fuels were provided by BFLRF for use in this study, and they were identified as Fuels C1, C2, and C3.

The test sequence used was similar to that specified by the California Air Resources Board (CARB) to assess similarity of two fuels, and is based on transient emission test procedures developed by the EPA for emissions regulatory purposes. For this study, the test process, given in Table 1, employed two heavy-duty diesel engines. One was a prototype 1991 DDC Series 60, and the other was a 1990 GM 6.2L V-8. The DDC Series 60 heavy-duty diesel engine has been used as the "test bench" for comparing engine emissions using a California reference fuel to those using a candidate equivalent fuel.

A batch of JP-8 fuel was secured by BFLRF from the U.S. Air Force in sufficient quantity to use as a "neat" low-sulfur fuel, identified as Fuel C1. This fuel also served as base fuel for preparation of Fuels C2 and C3, containing increased levels of sulfur. Sulfur contents of Fuels C1, C2, and C3 were 600, 2,600, and 1,100 ppm, respectively. Selected properties of the 2D fuel and JP-8 Fuels C1, C2, and C3 are summarized in Table 2. Fuel specifications and analysis of the 2D fuel and the JP-8 fuels are provided in Appendix A.

The test procedure in Table 1 incorporates steps for instrumentation and sample system calibration, changing fuel, establishing engine performance and transient testing, sample analysis, and review of emissions data. Emission results of HC, CO, NO_x, total particulate matter (PM), sulfate, and SOF in units of g/hp-hr, BSFC (by carbon balance) in units of lb/hp-hr, and work in units of hp-hr were accumulated over several hot-start transient tests. The test sequence in Table 1 was expected to yield enough useful emissions

TABLE 1. PROCEDURE FOR ACCUMULATING REGULATED EMISSIONS DATA USING HOT-START TRANSIENT TESTING

Step	Description
1	Install 1991 DDC Series 60 heavy-duty diesel engine in transient-capable test cell. Fill with prescribed engine oil. Perform emission instrument calibrations as required. Calibrate torquemeter and check signal conditioning systems. Validate CVS gaseous and particulate sampling systems using propane recovery techniques.
2	Check engine condition using in-house, low sulfur 2D emissions type fuel, and note fault codes if any. Bring engine oil level to "full" using REO-216 oil.
3	On Day 1 of testing, perform fuel change procedure to operate on designated Fuel 2D. Change filter, purge fuel supply, etc.
4	Warm up engine and operate at rated speed and load, then check performance.
5	Conduct transient "full-throttle" torque-map from low- to high-idle. Compute and store resulting transient command cycle. This initial transient command cycle with reference Fuel 2D will be used for all subsequent emission tests in this test plan. Other torque-map information generated with either Fuel 2D or candidate fuels during this test work will be stored for documentation purposes.
6	Run two 20-minute practice or conditioning transient cycles without a 20-minute soak between cycles, and adjust dynamometer controls to meet statistical limits for transient cycle operation.
7	After a 20-minute engine soak, run a hot-start transient cycle for HC, CO, NO_x, and total particulate (PM) emissions. Obtain additional samples of total particulate for sulfate and SOF.
8	Repeat Steps 3 - 7 with Fuel C1. After 20-minute engine soak, conduct a second hot-start transient cycle for HC, CO, NO_x, PM, sulfate, and SOF emissions.
9	Repeat Steps 3 - 7 with Fuel 2D.
10	On Day 2 of testing, repeat Steps 4 - 7 with Fuel 2D.
11	Repeat Step 8 with Fuel C1.
12	Repeat Steps 3 - 7 with Fuel 2D

TABLE 1. (Cont'd) PROCEDURE FOR ACCUMULATING REGULATED EMISSIONS DATA USING HOT-START TRANSIENT TESTING

Step	Description
13	On Day 3 of testing, repeat Steps 4 - 7 with Fuel 2D.
14	Repeat Step 8 with Fuel C2.
15	Repeat Steps 3 - 7 with Fuel 2D.
16	On Day 4 of testing, repeat Steps 4 - 7 with Fuel 2D.
17	Repeat Step 8 with Fuel C3.
18	Repeat Steps 3 - 7 with Fuel 2D.
19	On Day 5 of testing, repeat Steps 4 - 7 with Fuel 2D.
20	Repeat Step 8 with Fuel C3.
21	Repeat Steps 3 - 7 with Fuel 2D.
22	Repeat Steps 1- 21 with 1990 GM 6.2L V-8 heavy duty control diesel engine. In Step 1, install engine oil cooler as required to control engine's operating oil temperature. In Step 2, bring engine oil level to "full" using prescribed oil.
23	Summarize emissions data and prepare final report.

TABLE 2. IDENTITY OF REFERENCE AND CANDIDATE DIESEL FUELS

Test Fuel ID	SwRI Fuel Code	Base Fuel	Sulfur Concentration, wt.%	Cetane No.	Aromatic Content, wt. %
2D	1749[a]	2D	0.04	45.8	31.4
C1	1809[b]	C1	0.06	45.5	20.5
C2	1816[c]	C1	0.26	45.5	20.5
C3	1818[d]	C1	0.11	45.5	20.5

[a]1745: low sulfur, No. 2 grade reference diesel fuel
[b]1809: neat JP-8 candidate fuel received from Kelly AFB, San Antonio, Texas
[c]1816: 99.44 Vol % 1809 + 0.56 Vol % DTBDS
[d]1818: 99.86 Vol % 1809 + 0.14 Vol % DTBDS

information to identify fuel formulations with potential to significantly reduce emissions. An estimate of typical precision and accuracy for emissions of HC, CO, NO_x, PM, sulfate, and SOF is provided in Appendix B. The information is an excerpt from the Quality Assurance (QA) Plan used in emissions testing of CARB equivalent fuel candidates. This data-assessment procedure was used to review the precision and accuracy of the emissions data obtained in this program.

II. TEST PROCEDURES

This section describes the engine tested and the fuel system used to supply test fuels to the engines. The procedure for mapping the torque performance of the engine is given and a brief description of techniques used in measuring regulated and selected unregulated emissions is provided.

A. Test Engines and Setup

The two heavy-duty diesel engines used in this study were a 1991 prototype DDC Series 60 and a 1990 GM 6.2L V-8. Some of the characteristics of these engines are given in Table 3. In turn, both engines were installed in a transient-capable test cell.

The Series 60 engine had a nominal rated power of 330 hp at 1800 rpm. It was designed to use an air-to-air intercooler; however, for dynamometer test work, a test cell intercooler with water-to-air heat exchanger was used. No auxilliary engine cooling was required. This engine had been used in other fuel studies so it was ready for test work in this program.

The GM 6.2L engine was a new engine. Prior to use in this work the engine completed a 125-hr service accumulation run on an engine-dynamometer test stand located at the BFLRF laboratory. The service accumulation was conducted as specified by the GM Powertrain Group in Romulus, Michigan. Installation of the GM 6.2L engine in the DER transient-capable test cell required adaptation of an auxilliary oil cooler to the engine in order to meet the specified oil operating temperature. Rated power of the naturally aspirated GM 6.2L engine was 150 hp at 3600 rpm.

Intake air for each engine was obtained from the humidity- and temperature-controlled engine inlet air system, such that the NO_x correction factor was 1.00 ± 0.03. Both intake and exhaust restrictions were set with dampers. Engine coolant systems were closed-loop, using a 50/50 mixture of ethylene glycol and water.

Engine flywheel torque was measured directly using a calibrated torquemeter in the drive coupling connecting the engine to the motor/load dynamometer system. During the emissions test work, the engine's fuel control signal ("throttle") position was moved using a servo-controller. The servo-controller activity was based on control signals sufficient to cause the engine to operate over the transient command cycle. To judge how well the engine followed the transient cycle command, engine responses were compared to engine commands and several statistics were computed for comparison to tolerances specified for the transient Federal Test Procedure (FTP). The engine control and response statistics were checked to ensure that the FTP validation criteria were met, or adjustments were made to improve the statistics prior to actual testing.

TABLE 3. CHARACTERISTICS OF THE PROTOTYPE 1991 DDC SERIES 60 ENGINE AND THE 1990 GM 6.2L HEAVY-DUTY DIESEL ENGINE

	DDC SERIES 60	GM 6.2L
Engine Configuration and Displacement	6-Cylinder, 11.1 Liter, 130 mm Bore x 139 mm Stroke	90° V-8 Cylinder, 6.2 Liter, 101 mm Bore x 97 mm Stroke, 21.5:1 Compression Ratio
Aspiration	Turbocharged, Aftercooled (Air-to-Air),	Naturally Aspirated
Emission Controls	Electronic Management of Fuel Injection and Timing (DDEC-II)	Mechanical Fuel Injection Advance and Crankcase Ventilation
Rated Power	330 hp at 1800 rpm with 108 lb/hr Fuel	150 hp at 3600 rpm with 72 lb/hr Fuel
Peak Torque	1270 lb-ft at 1200 rpm with 93 lb/hr Fuel	257 lb-ft at 2400 rpm with 52 lb/hr Fuel
Injection	Direct Injection, Electronically Controlled Unit Injectors	Rotary Distributor Injection Pump with Pintle Injectors, Indirect Injection with High Swirl Pre-Combustion Chamber
Maximum Restrictions Exhaust Intake	 2.9 in. Hg at Rated Conditions 20 in. H_2O at Rated Conditions	 7.5 in. Hg at Rated Conditions 15.3 in. H_2O at Rated Conditions
Low Idle Speed	600 rpm	700 rpm

B. Fuel System

Fuel was supplied to the engine connection and returned from the "engine spill" connection at atmospheric pressure using a "day tank" maintained at a level controlled by a simple float valve. Fuel supplied to the "day tank" was provided through a pump and filter arrangement drawing fuel from the bulk drum (55 gallon drum). The temperature of the fuel delivered to the engine was monitored (as specified by the manufacturer) and controlled to range from a minimum of 68°F to a maximum of 110°F.

After completing test work on a selected fuel, a drum of the next fuel was normally staged in the test cell area one day or more prior to its intended use so that it would be stabilized at room temperature (68 to 86°F). As outlined below, the API gravity of the selected fuel was measured to cross check the identity of the fuel. After approval to switch fuels was given; fuel system lines, filters, heat exchanger, and return tank were drained. New fuel filters and the supply tank were filled with the selected fuel. With the exhaust routed into the Constant Volume Sampling (CVS) system, the engine was operated on the selected fuel at moderate load, and the fuel return spillage was collected. The initial three gallons of this return fuel were discarded. Additional return fuel was periodically monitored for API gravity. If the API gravity of the return fuel did not agree with that of the selected fuel, it also was discarded. Usually after a total of four to five gallons had been returned, the API gravity of the return fuel agreed with that of the selected fuel supplied.

Fuel Change Process

- Identify and Confirm Fuel API Gravity
- Drain: Lines, Filters, and Supply Tank Heat Exchangers
- Refill: New Filters with New Fuel
- Purge fuel (Engine at Intermediate Speed/50% Load)
- Power Validation (Transient Restrictions)
- Transient Map
- Practice Transient

After the return fuel showed evidence that it was in fact the desired test fuel, the engine was taken to rated power conditions and held for a period of time to set the intake and exhaust restrictions to the manufacturer's recommended transient restrictions. After about 5 to 10 minutes, "power validation" readings were taken. Power validation pertains to recording engine performance data along with various engine parameters at rated power and peak torque. After checking high-idle and low-idle parameters, the engine was taken back up to rated power conditions and the intake and exhaust restrictions were checked to meet the "typical" values used during transient testing.

C. Torque Map

The engine was "torque mapped" according to the transient FTP procedure, using full rack from slightly below low-idle speed to above rated speed and increasing engine speed at a rate of 8 rpm per second. Data from this transient torque map were used in conjunction with the FTP-specified speed and load percentages to form a transient command cycle. This performance-based transient command cycle is characteristic of the fuel and engine combination. For this work, the performance-based transient cycle was termed a "fuel-derived transient cycle," because only the fuel was changed and no engine adjustments were made.

Prior to a hot-start transient test sequence for emission measurement purposes, a preconditioning sequence was followed after changing fuels or after any engine operation other than a hot-start transient cycle. The preconditioning sequence consisted of two practice transient cycles (without 20-minute soak) run with exhaust through the CVS tunnel, and with all particulate filter sampling stations in operation utilizing unrecorded filter media.

Heavy-duty diesel engine emission standards are based on the "transient FTP test" results of the engine tested over cold-start and hot-start operation. The same engine control or fuel-derived transient command cycle is used in both cases. For purposes of this study, only hot-start transient cycles were employed for emission characterization.

D. Regulated and Unregulated Emissions Sampling and Analyses

Regulated and selected unregulated emissions were measured during hot-start transient engine cycles. Regulated emission measurements and sampling techniques were based on transient emission test procedures specified by the EPA in CFR 40, Part 86, Subpart N for emissions regulatory purposes. For the purposes of this study, regulated emissions of HC, CO, NO_x, and particulate matter (PM), along with unregulated emissions of sulfate and SOF, were measured as described in the following paragraphs.

Hydrocarbon (HC) emissions were determined using a heated FID as prescribed in the FTP for transient emissions testing. Hydrocarbon emissions determined from CVS dilute samples are dependent on background measurement. Background hydrocarbon levels of the CVS dilution air were determined with on-line heated FID just before and after each transient test, and were used as the averaged "background" level for computation of the HC emissions. On-line FID background HC levels were relatively constant during the course of the transient test.

Carbon monoxide and CO_2 emissions were determined from dilute exhaust samples collected in a sample bag using NDIR instruments set up according to applicable EPA FTP. Measurement of CO_2 was of interest because it was used in the calculation of fuel consumption by carbon balance, along with CO and HC emissions. Oxides of nitrogen (NO_x) were determined using the CVS with a heated sampling train. The NO_x concentration of the continuous sample was determined by chemiluminescence (CL) and integrated over the transient test cycle. EPA NO_x correction factors for engine inlet air humidity and temperature were applied.

Total particulate is defined as any material collected on a fluorocarbon-coated glass fiber filter at or below the temperature of 51.7°C (125°F), excluding condensed water. Total particulate emissions were determined using a double-dilution technique specified in the EPA 1988 transient FTP for heavy-duty diesel engines. The double-dilution system utilized dry gas meters to measure the flow of dilution air and the total flow through a set of 90 mm Pallflex (T60A20) filters positioned in series. Weight gains from these two filters, one primary and the other a backup, were used to determine the total particulate.

Additional samples of PM were collected during each transient cycle for determination of sulfate and SOF. An ion chromatograph procedure was used to assess the sulfate levels contained in PM samples collected on 47 mm Fluoropore filter media during the transient test work. This procedure does not measure the sulfate-bound water that accounts for additional weight measured as PM. SOF was determined by extracting particulate-laden 47 mm Pallflex filters using a micro-Soxhlet apparatus with toluene-ethanol solvent, as specified by CARB.

III. TEST RESULTS

The torque-map results obtained with the prototype 1991 DDC Series 60 and with the 1990 GM 6.2L heavy-duty diesel engine using Fuels 2D, C1, C2, and C3, are given in corresponding Tables 4 and 5. These tables include percent difference in average torque between Fuel 2D and the JP-8 fuels. Initial torque information shown for each engine on Fuel 2D was the basis for the transient command cycle used for all subsequent hot-start emissions tests run on that engine.

Illustrations of the average of engine torque-maps obtained using each of Fuels 2D, C1, C2, and C3 are given in Figures 1 and 2 for the Series 60 and GM 6.2L, respectively. Torque differences between candidate fuels on each engine were generally within test-to-test repeatability observed when using the same fuel. Because an engine's full power performance is proportionally dependent on the mass of fuel injected into the engine, engine performance levels on JP-8 fuels were always lower than on Fuel 2D, a more dense fuel. Average torque levels were 9 and 12 percent lower with the JP-8 fuels as compared to Fuel 2D for the Series 60 and for the GM 6.2L engine, respectively.

Individual and averaged hot-start transient HC, CO, NO_x, PM, and SOF emissions results are given in Table 6 for the Series 60 engine, and in Table 7 for the GM 6.2L engine. Means and standard deviations, provided in Tables 6 and 7, are reported to an extended number of places for use in more detailed comparison. Computer printouts of emissions results, arranged in order of testing, are provided in Appendix C for the Series 60 engine, and in Appendix D for the GM 6.2L engine.

For summary purposes, a selected statistical method for comparing means was applied to the test data, and the results are given in Tables 8 through 10 for the 1991 prototype Series 60, and also in Tables 11 through 13 for the 1990 GM 6.2L engine. The statistical method examined the hypothesis that the population mean value for an emission on one fuel did not differ from the population mean value for that emission on the other fuel, essentially saying that the emissions on the two fuels do not differ. Because all of the requirements of the statistical method for random test sequence were not met, the results obtained using this statistical method were applied only for summarization purposes. Accepting or rejecting the hypothesis is always subject to change with further testing.

In this report, the hypothesis was accepted or rejected on the basis of a 5 percent significance level (a 95 percent confidence level) as determined using a two-sided Student "t" statistic. Use of a different significance level, random sampling, or a larger sample size could result in a different conclusion. The equation for calculating "t" is:

TABLE 4. TRANSIENT TORQUE MAPS OBTAINED WITH A PROTOTYPE 1991 DDC SERIES 60 USING FUELS 2D, C1, C2, AND C3

Engine Speed, rpm	Transient Map Torque on Test Fuels, lb-ft														
	TEST DAY 1			TEST DAY 2			TEST DAY 3			TEST DAY 4			TEST DAY 5		
	Fuel 2D(a)	Fuel C1	Fuel 2D	Fuel 2D	Fuel C1	Fuel 2D	Fuel 2D	Fuel C2	Fuel 2D	Fuel 2D	Fuel C3	Fuel 2D	Fuel 2D	Fuel C3	Fuel 2D
600	809	762	809	810	761	816	814	758	824	812	757	818	811	760	816
700	860	806	856	863	804	864	863	801	873	866	802	869	862	805	865
800	915	845	914	918	842	917	917	838	926	922	838	921	919	844	914
900	1014	935	1011	1014	933	1018	1017	931	1026	1018	931	1022	1017	936	1019
1000	1122	1030	1120	1127	1030	1128	1128	1029	1139	1133	1026	1133	1128	1031	1130
1100	1197	1069	1190	1197	1070	1200	1206	1072	1215	1211	1069	1207	1201	1069	1200
1200	1288	1186	1286	1291	1181	1293	1294	1178	1305	1294	1181	1298	1293	1182	1300
1300	1272	1170	1268	1273	1170	1277	1276	1166	1285	1283	1164	1278	1277	1168	1278
1400	1213	1111	1206	1215	1113	1214	1215	1107	1221	1220	1106	1219	1218	1108	1218
1500	1153	1058	1150	1157	1057	1157	1157	1053	1165	1159	1051	1155	1155	1056	1160
1600	1108	1018	1102	1111	1015	1108	1112	1008	1117	1114	1008	1110	1111	1010	1112
1700	1053	964	1047	1058	966	1054	1055	956	1063	1059	955	1058	1056	958	1058
1800	991	908	987	996	908	995	996	900	1003	999	903	996	996	906	998

(a) Total ideal work with Fuel 2D was 23.06 hp-hr. No intrinsic ideal work or reference work was computed from torque-maps generated on remaining fuels because they were not used. Initial Fuel R torque-map was the basis for the transient cycle used on all following fuels.

TABLE 4 (CONT'D). TRANSIENT TORQUE MAPS OBTAINED WITH A PROTOTYPE 1991 DDC SERIES 60 USING FUELS 2D, C1, C2, AND C3

Engine Speed, rpm	Average Transient Map Torque, lb-ft				Percent Diff. From Torque on Fuel 2D		
	Fuel 2D	Fuel C1	Fuel C2	Fuel C3	Fuel C1	Fuel C2	Fuel C3
600	814	762	758	759	–6.4	–6.9	–6.8
700	864	805	801	804	–6.8	–7.3	–7.0
800	918	844	838	841	–8.1	–8.7	–8.4
900	1018	934	931	934	–8.2	–8.5	–8.3
1000	1129	1030	1029	1029	–8.8	–8.8	–8.9
1100	1202	1070	1072	1069	–11.1	–10.8	–11.1
1200	1294	1184	1178	1182	–8.6	–9.0	–8.7
1300	1277	1170	1166	1166	–8.4	–8.7	–8.7
1400	1216	1112	1107	1107	–8.5	–9.0	–9.0
1500	1157	1058	1053	1054	–8.6	–9.0	–8.9
1600	1111	1017	1008	1009	–8.5	–9.2	–9.1
1700	1056	965	956	957	–8.6	–9.5	–9.4
1800	996	908	900	905	–8.8	–9.6	–9.2
				Average	–8.4	–8.8	–8.7

TABLE 5. TRANSIENT TORQUE MAPS OBTAINED WITH A 1990 GM 6.2L DIESEL ENGINE USING FUELS 2D, C1, C2, AND C3

Engine Speed, rpm	Transient Map Torque on Test Fuels, lb-ft														
	TEST DAY 1			TEST DAY 2			TEST DAY 3			TEST DAY 4			TEST DAY 5		
	Fuel 2D(a)	Fuel C1	Fuel 2D	Fuel 2D	Fuel C1	Fuel 2D	Fuel 2D	Fuel C2	Fuel 2D	Fuel 2D	Fuel C3	Fuel 2D	Fuel 2D	Fuel C3	Fuel 2D
700	207	176	211	210	169	209	213	168	211	211	166	211	215	162	210
800	215	182	218	218	177	218	222	177	220	219	177	221	223	174	219
900	219	187	223	223	184	222	227	185	225	225	185	226	228	184	225
1000	226	193	228	230	190	228	233	192	230	230	192	231	232	190	230
1100	232	196	234	235	194	233	240	195	236	237	196	236	237	194	235
1200	239	202	241	243	200	241	247	202	242	243	202	243	245	201	243
1300	245	209	249	250	208	248	251	210	249	250	210	249	251	209	247
1400	250	215	252	252	215	252	255	215	253	253	217	253	255	216	251
1500	253	220	255	255	219	254	258	220	255	254	224	256	256	219	254
1600	254	224	256	256	223	254	259	225	256	256	226	255	257	224	254
1700	254	228	256	257	229	255	259	230	255	258	229	256	258	229	255
1800	257	234	260	258	233	258	261	236	258	259	235	259	259	233	255
1900	257	238	260	260	236	260	261	239	259	259	238	259	260	237	258
2000	257	239	259	261	239	258	262	242	260	260	241	259	262	240	259
2100	257	239	259	260	240	258	261	240	258	261	240	259	261	240	257
2200	257	238	260	259	238	258	261	240	259	259	239	259	260	238	257
2300	256	235	259	260	236	257	261	239	259	260	238	258	260	236	257
2400	255	234	257	258	235	257	259	237	258	258	236	256	259	235	255
2500	255	233	258	257	234	257	258	236	256	256	235	256	257	234	253
2600	252	231	256	256	232	254	256	235	255	255	233	253	254	231	251
2700	252	230	253	253	231	252	254	233	253	253	231	252	253	229	249
2800	250	229	253	252	230	253	253	231	251	251	229	251	252	228	249
2900	249	228	252	251	228	250	252	230	250	251	227	249	251	227	248
3000	247	225	250	248	226	249	250	227	247	248	226	247	247	221	244
3100	244	223	246	246	224	245	247	226	243	245	222	245	246	222	242
3200	241	219	243	241	220	240	241	223	238	241	221	240	241	216	238
3300	235	216	238	238	218	236	239	219	234	237	218	236	237	215	234
3400	231	213	233	233	214	232	233	215	230	233	214	231	232	212	229
3500	225	206	228	227	208	227	228	208	225	227	208	225	227	199	223
3600	218	199	221	219	200	219	220	200	217	219	198	219	220	196	215
3700	190	171	192	189	169	185	188	167	185	195	170	191	194	157	189
3800	144	125	141	136	116	129	131	110	118	127	101	121	120	90	111
3900	42	27	45	40	25	36	39	24	38	38	20	41	36	13	36

(a) Total ideal work with Fuel 2D was 9.98 hp-hr. No intrinsic ideal work or reference work was computed from torque-maps generated on remaining fuels because they were not used. Initial Fuel R torque-map was the basis for the transient cycle used on all following fuels.

TABLE 5 (CONT'D). TRANSIENT TORQUE MAPS OBTAINED WITH A 1990 GM 6.2L DIESEL ENGINE USING FUELS 2D, C1, C2, AND C3

Engine Speed, rpm	Average Transient Map Torque, lb-ft				Percent Diff. From Torque on Fuel 2D		
	Fuel 2D	Fuel C1	Fuel C2	Fuel C3	Fuel C1	Fuel C2	Fuel C3
700	211	173	168	164	−18.2	−20.3	−22.2
800	219	180	177	176	−18.1	−19.3	−20.0
900	224	186	185	185	−17.3	−17.5	−17.7
1000	230	192	192	191	−16.7	−16.4	−16.9
1100	236	195	195	195	−17.2	−17.2	−17.2
1200	243	201	202	202	−17.2	−16.8	−17.0
1300	249	209	210	210	−16.2	−15.6	−15.8
1400	253	215	215	217	−14.9	−14.9	−14.3
1500	255	220	220	222	−13.9	−13.7	−13.1
1600	256	224	225	225	−12.6	−12.0	−12.0
1700	256	229	230	229	−10.8	−10.3	−10.7
1800	258	234	236	234	−9.6	−8.7	−9.4
1900	259	237	239	238	−8.6	−7.8	−8.4
2000	260	239	242	241	−8.0	−6.8	−7.4
2100	259	240	240	240	−7.6	−7.4	−7.4
2200	259	238	240	239	−8.1	−7.3	−7.9
2300	259	236	239	237	−9.0	−7.6	−8.4
2400	257	235	237	236	−8.8	−7.9	−8.4
2500	256	234	236	235	−8.9	−7.9	−8.5
2600	254	232	235	232	−8.9	−7.6	−8.7
2700	252	231	233	230	−8.7	−7.7	−8.9
2800	252	230	231	229	−8.7	−8.2	−9.1
2900	250	228	230	227	−8.9	−8.1	−9.3
3000	248	226	227	224	−9.0	−8.4	−9.8
3100	245	224	226	222	−8.7	−7.7	−9.4
3200	240	220	223	219	−8.7	−7.2	−9.1
3300	236	217	219	217	−8.2	−7.4	−8.4
3400	232	214	215	213	−7.9	−7.2	−8.1
3500	226	207	208	204	−8.5	−8.0	−10.0
3600	219	200	200	197	−8.8	−8.6	−9.9
3700	190	170	167	164	−10.4	−12.0	−13.9
3800	128	121	110	96	−5.7	−13.9	−25.3
3900	39	26	24	17	−33.5	−38.6	−57.8
				Average	−11.7	−11.7	−13.3

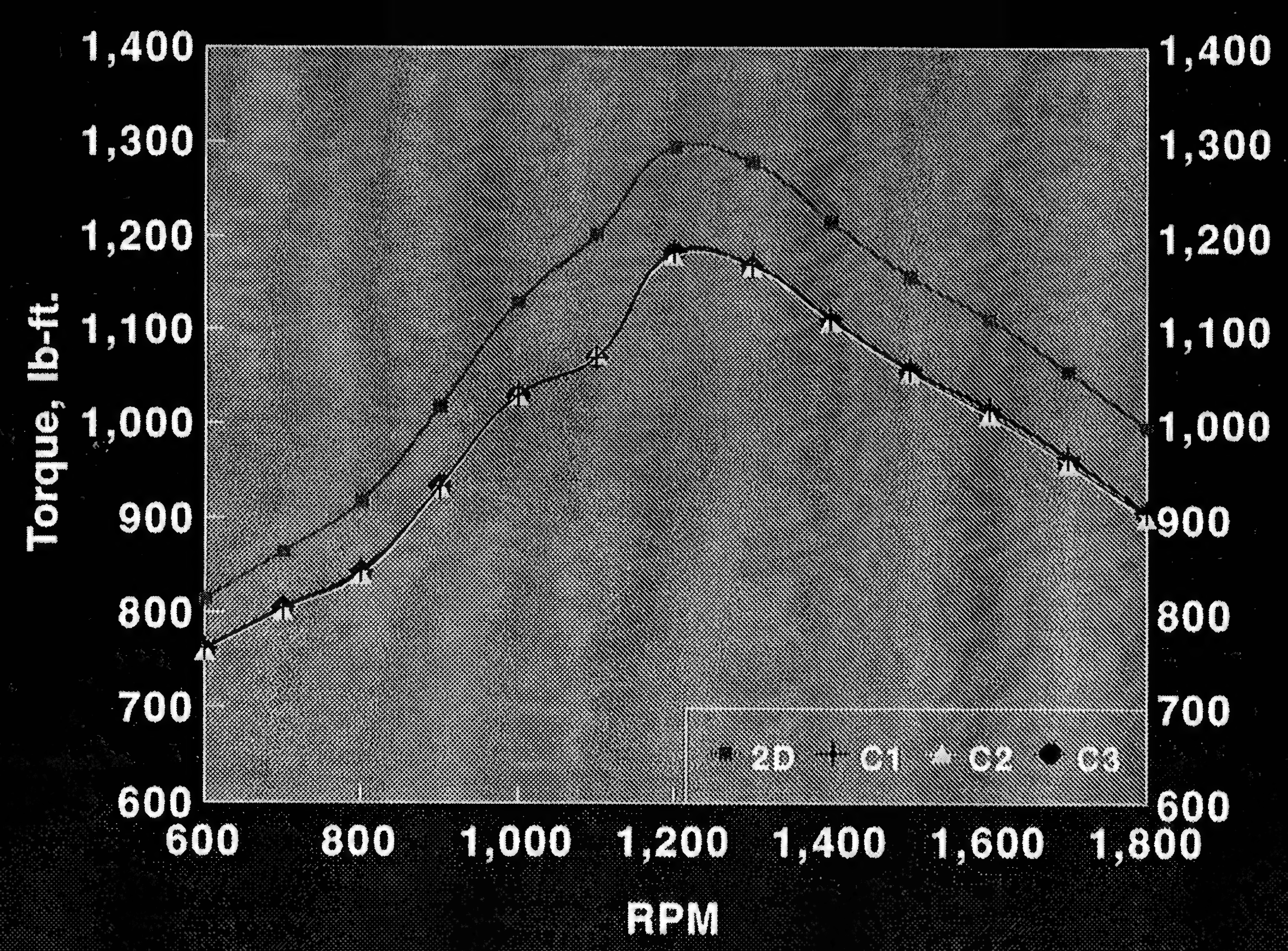

FIGURE 1. AVERAGE TRANSIENT TORQUE MAPS OF THE PROTOTYPE 1991 DDC SERIES 60 USING FUELS 2D, C1, C2, AND C3

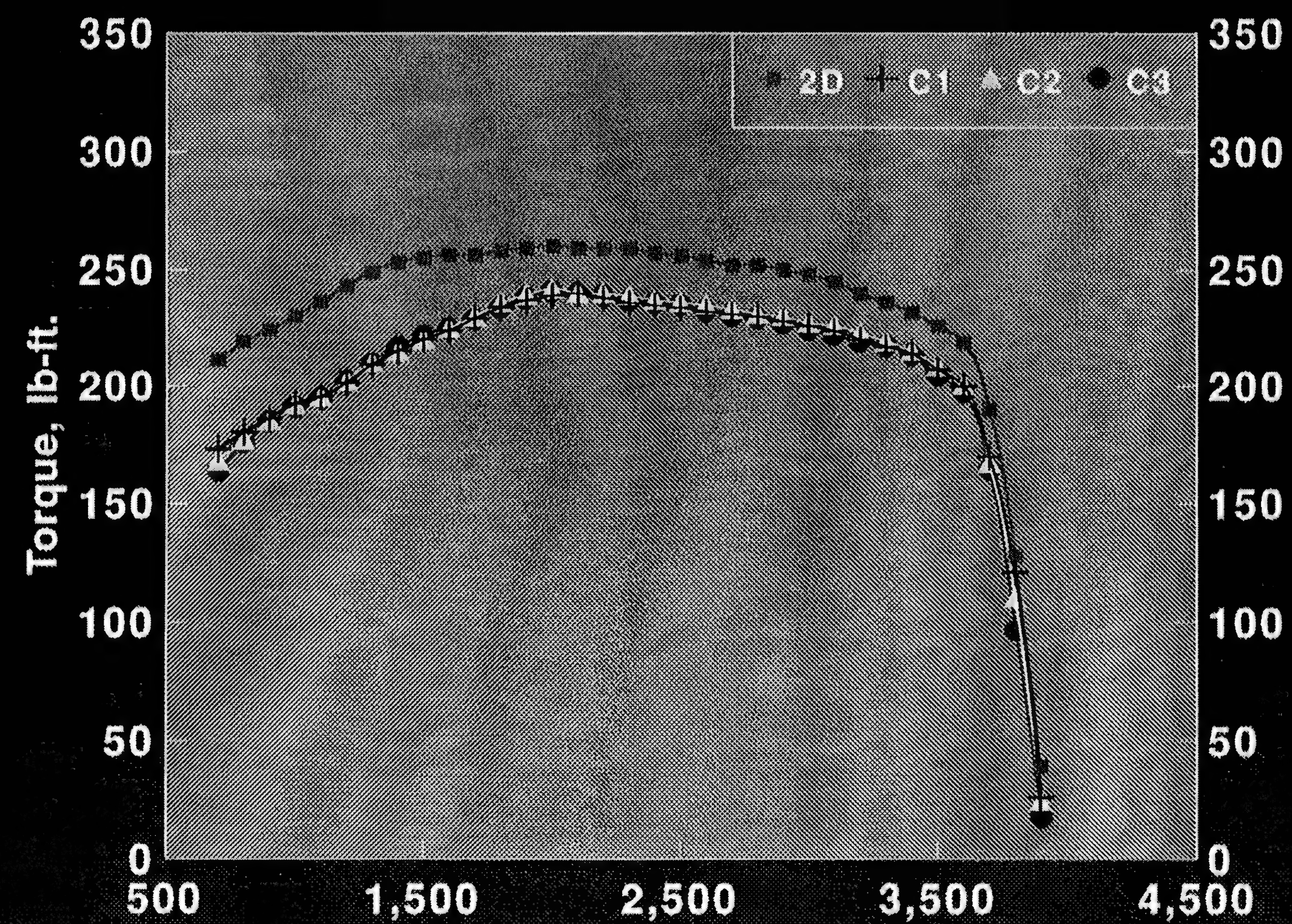

FIGURE 2. AVERAGE TRANSIENT TORQUE MAPS OF THE 1990 GM 6.2L DIESEL ENGINE USING FUELS 2D, C1, C2, AND C3

TABLE 6. HOT-START TRANSIENT EMISSIONS FROM A PROTOTYPE 1991 DDC SERIES 60 USING FUELS 2D, C1, C2, AND C3

Date	Run Order	Test Day	Test	Fuel Code	Hot Start Transient Emissions, g/hp-hr						BSFC, lb/hp-hr	Work, hp-hr	Ref. Work, hp-hr
					HC	CO	NOx	PM	Sulfate	SOF			
6/8/94	1	1	R06084A	2D	0.488	1.923	4.476	0.169	0.0032	0.049	0.395	22.46	23.06
6/8/94	2	1	C106084A	C1	0.546	1.596	4.460	0.134	0.0052	0.038	0.387	22.04	23.06
6/8/94	3	1	C106084B	C1	0.542	1.619	4.634	0.130	0.0056	0.037	0.393	21.88	23.06
6/8/94	4	1	R06084B	2D	0.524	1.914	4.488	0.166	0.0030	0.046	0.395	22.49	23.06
6/9/94	5	2	R06094A	2D	0.504	1.927	4.414	0.163	0.0029	0.044	0.395	22.43	23.06
6/9/94	6	2	C106094A	C1	0.550	1.620	4.421	0.131	0.0053	0.036	0.387	22.17	23.06
6/9/94	7	2	C106094B	C1	0.565	1.647	4.504	0.133	0.0053	0.036	0.389	22.05	23.06
6/9/94	8	2	R06094B	2D	0.560	1.974	4.358	0.168	0.0030	0.047	0.391	22.41	23.06
6/10/94	9	3	R06104A	2D	0.523	1.879	4.430	0.169	0.0034	0.054	0.401	22.06	23.06
6/10/94	10	3	C206104A	C2	0.551	1.572	4.357	0.176	0.0248	0.093	0.384	21.76	23.06
6/10/94	11	3	C206104B	C2	0.555	1.580	4.369	0.177	0.0254	0.083	0.385	21.80	23.06
6/10/94	12	3	R06104B	2D	0.530	1.966	4.447	0.167	0.0030	0.048	0.396	22.37	23.06
6/13/94	13	4(a)	C306134A	C3	0.612	1.693	4.452	0.161	0.0100	0.057	0.392	21.61	23.06
6/13/94	14	4(a)	C306134B	C3	0.643	1.728	4.339	0.148	0.0091	0.070	0.385	21.82	23.06
6/13/94	15	4(a)	R06134B	2D	0.578	1.967	4.419	0.177	0.0031	0.056	0.395	22.27	23.06
6/13/94	16	4(a)	R06134C	2D	0.562	1.920	4.371	0.171	0.0028	0.054	0.392	22.32	23.06
6/15/94	17	5	R06154A	2D	0.523	1.892	4.342	0.175	0.0029	0.054	0.390	22.42	23.06
6/15/94	18	5	C306154A	C3	0.632	1.643	4.324	0.154	0.0085	0.055	0.383	22.03	23.06
6/15/94	19	5	C306154B	C3	0.632	1.720	4.346	0.150	0.0106	0.059	0.390	21.89	23.06
6/15/94	20	5	R06154B	2D	0.556	1.906	4.386	0.172	0.0032	0.053	0.391	22.46	23.06
Overall Results													
Days 1 & 2			C1 Mean		0.5508	1.6205	4.5048	0.1320	0.0054	0.0368	0.3890	22.035	23.06
			Std. Dev.		0.0100	0.0209	0.0926	0.0018	0.0002	0.0010	0.0028	0.119	NA
Days 1 & 2			2D Mean		0.5190	1.9345	4.4340	0.1665	0.0030	0.0465	0.3940	22.448	23.06
			Std. Dev.		0.0310	0.0269	0.0602	0.0026	0.0001	0.0021	0.0020	0.035	NA
Day 3			C2 Mean		0.5530	1.5760	4.3630	0.1765	0.0251	0.0880	0.3845	21.780	23.06
			Std. Dev.		0.0028	0.0057	0.0085	0.0007	0.0004	0.0071	0.0007	0.028	NA
Day 3			2D Mean		0.5265	1.9225	4.4385	0.1680	0.0032	0.0510	0.3985	22.215	23.06
			Std. Dev.		0.0049	0.0615	0.0120	0.0014	0.0003	0.0042	0.0035	0.219	NA
Days 4 & 5			C3 Mean		0.6298	1.6960	4.3653	0.1533	0.0096	0.0603	0.3875	21.838	23.06
			Std. Dev.		0.0129	0.0384	0.0586	0.0057	0.0009	0.0067	0.0042	0.175	NA
Days 4 & 5			2D Mean		0.5548	1.9213	4.3795	0.1738	0.0030	0.0543	0.3920	22.368	23.06
			Std. Dev.		0.0231	0.0326	0.0320	0.0028	0.0002	0.0013	0.0022	0.088	NA

(a) Note "CCRR" test sequence instead of "RCCR". First Fuel R test on this day was voided, and additional Fuel R was run.

TABLE 7. HOT-START TRANSIENT EMISSIONS FROM A 1990 GM 6.2L DIESEL ENGINE USING FUELS 2D, C1, C2, AND C3

Date	Run Order	Test Day	Test	Fuel Code	Hot Start Transient Emissions, g/hp-hr HC	CO	NOx	PM	Sulfate	SOF	BSFC, lb/hp-hr	Work, hp-hr	Ref. Work, hp-hr
9/23/94	1	1	R0923A8	2D	0.527	1.932	3.186	0.290	0.0027	0.113	0.578	9.89	9.98
9/23/94	2	1	C10923A8	C1	0.706	2.192	3.178	0.227	0.0039	0.089	0.586	9.71	9.98
9/23/94	3	1	C10923B8	C1	0.676	2.136	3.179	0.228	0.0042	0.095	0.633	9.73	9.98
9/23/94	4	1	R0923B8	2D	0.507	1.915	3.216	0.302	0.0028	0.100	0.584	9.79	9.98
9/26/94	5	2	R0926A8	2D	0.471	1.881	3.312	0.311	0.0029	0.108	0.591	9.83	9.98
9/26/94	6	2	C10926A8	C1	0.620	2.094	3.265	0.229	0.0042	0.099	0.592	9.67	9.98
9/26/94	7	2	C10926B8	C1	0.557	2.038	3.245	0.231	0.0039	0.087	0.590	9.72	9.98
9/26/94	8	2	R0926B8	2D	0.466	1.851	3.274	0.316	0.0025	0.102	0.601	9.82	9.98
9/27/94	9	3	R0927A8	2D	0.491	1.949	3.242	0.305	0.0026	0.087	0.589	9.88	9.98
9/27/94	10	3	C20927A8	C2	0.404	1.798	3.228	0.269	0.0214	0.116	0.591	9.65	9.98
9/27/94	11	3	C20927C8	C2	0.419	1.711	3.252	0.274	0.0219	0.113	0.588	9.68	9.98
9/27/94	12	3	R0927B8	2D	0.362	1.777	3.284	0.287	0.0032	0.090	0.596	9.78	9.98
9/28/94	13	4	R0928A8	2D	0.473	1.785	3.200	0.284	0.0026	0.077	0.596	9.91	9.98
9/28/94	14	4	C30928B8	C3	0.427	1.804	3.258	0.225	0.0083	0.066	0.598	9.59	9.98
9/28/94	15	4	C30928C8	C3	0.455	1.854	3.226	0.233	0.0099	0.088	0.597	9.61	9.98
9/28/94	16	4	R0928B8	2D	0.392	1.746	3.360	0.275	0.0028	0.073	0.594	9.83	9.98
9/29/94	17	5	R0929A8	2D	0.428	1.773	3.176	0.272	0.0028	0.093	0.591	9.92	9.98
9/29/94	18	5	C30929A8	C3	0.419	1.699	3.242	0.225	0.0095	0.089	0.593	9.68	9.98
9/29/94	19	5	C30929B8	C3	0.444	1.730	--(a)	0.230	0.0107	0.086	0.595	9.71	9.98
9/29/94	20	5	R0929B8	2D	0.423	1.613	3.269	0.263	0.0029	0.087	0.569	10.00	9.98
Overall Results													
Days 1 & 2			C1 Mean		0.6398	2.1150	3.2168	0.2288	0.0041	0.0925	0.6003	9.708	9.98
			Std. Dev.		0.0657	0.0652	0.0449	0.0017	0.0002	0.0055	0.0220	0.026	NA
Days 1 & 2			2D Mean		0.4928	1.8948	3.2470	0.3048	0.0027	0.1058	0.5885	9.833	9.98
			Std. Dev.		0.0292	0.0361	0.0567	0.0114	0.0002	0.0059	0.0099	0.042	NA
Day 3			C2 Mean		0.4115	1.7545	3.2400	0.2715	0.0217	0.1145	0.5895	9.665	9.98
			Std. Dev.		0.0106	0.0615	0.0170	0.0035	0.0004	0.0021	0.0021	0.021	NA
Day 3			2D Mean		0.4265	1.8630	3.2630	0.2960	0.0029	0.0885	0.5925	9.830	9.98
			Std. Dev.		0.0912	0.1216	0.0297	0.0127	0.0004	0.0021	0.0049	0.071	NA
Days 4 & 5			C3 Mean		0.4363	1.7718	3.2420	0.2283	0.0096	0.0823	0.5958	9.648	9.98
			Std. Dev.		0.0163	0.0703	0.0160	0.0039	0.0010	0.0109	0.0022	0.057	NA
Days 4 & 5			2D Mean		0.4290	1.7293	3.2513	0.2735	0.0028	0.0825	0.5875	9.915	9.98
			Std. Dev.		0.0334	0.0792	0.0825	0.0087	0.0001	0.0091	0.0125	0.070	NA

(a)Voided errorneous NOx emissions data

TABLE 8. COMPARISON OF TRANSIENT HOT-START EMISSIONS SCREENING TEST CONDUCTED ON A PROTOTYPE 1991 DDC SERIES 60 HEAVY-DUTY DIESEL ENGINE ON REFERENCE FUEL 2D (R) AND A CANDIDATE FUEL C1 (C)

Results of Hot-Start Transient Screening Procedure	HC	CO	NO_x	Part.	Sulfate	SOF
R Mean, $\bar{x}_R$ [a]	0.5190	1.9345	4.4340	0.1665	0.003025	0.04650
R Std. Dev., s_R [a]	0.0310	0.0269	0.0602	0.0026	0.000126	0.00208
Sample Size, n_R	4	4	4	4	4	4
C Mean, $\bar{x}_C$ [a]	0.5508	1.6205	4.5048	0.1320	0.005350	0.03675
C Std. Dev., s_C [a]	0.0100	0.0209	0.0926	0.0018	0.000173	0.00096
Sample Size, n_C	4	4	4	4	4	4
Pooled Std. Dev. Sp[a,b]	0.0231	0.0241	0.0781	0.0023	0.000151	0.00162
Mean Difference [a,c]	0.0318	-0.3140	0.0708	-0.0345	0.002325	-0.00975
Degrees of Freedom [d]	6	6	6	6	6	6
Computed "t" [e]	1.946	-18.455	1.281	-21.465	21.720	-8.5105
Student "t" (0.95 Conf. Level)	2.447	2.447	2.447	2.447	2.447	2.447
Hypothesis: $\mu_C = \mu_R$ [f]	Accept	Reject	Accept	Reject	Reject	Reject
Statistical Conclusion[g]	**C=R**	**C<R**	**C=R**	**C<R**	**C>R**	**C<R**

CRITERIA AND LIMITATIONS associated with this statistical analysis of the data are described in a paragraph in Section III of this report; that paragraph by reference becomes an integral part of this table.

[a] Units for the Mean, Std. Dev., and Mean Difference are g/hp-hr.

[b] $Sp = \sqrt{[(n_C-1)S_C^2 + (n_R-1)S_R^2] / [(n_C-1) + (n_R-1)]}$ Pooled std. dev. is provided to show overall deviation of the test results.

[c] Mean Difference = $\bar{x}_C - \bar{x}_R$.

[d] Degrees of Freedom = $n_R + n_C - 2$.

[e] $t = (\bar{x}_C - \bar{x}_R) / \sqrt{(n_C - 1)\, s_C^2 + (n_R - 1)\, s_R^2} \times \sqrt{n_C n_R (n_C + n_R - 2) / (n_C + n_R)}$

[f] μ is the population mean (Hypothesis is that at 95 percent confidence level the population mean values for the two sets of test results do not differ).

[g] This conclusion indicates the emission level of candidate fuel relative to the emission level of reference fuel.

TABLE 9. COMPARISON OF TRANSIENT HOT-START EMISSIONS SCREENING TEST CONDUCTED ON A PROTOTYPE 1991 DDC SERIES 60 HEAVY-DUTY DIESEL ENGINE ON REFERENCE FUEL 2D (R) AND A CANDIDATE FUEL C2 (C)

Results of Hot-Start Transient Screening Procedure	HC	CO	NO_x	Part.	Sulfate	SOF
R Mean, $\bar{x}_R$ [a]	0.5265	1.9225	4.4385	0.1680	0.003200	0.05100
R Std. Dev., s_R [a]	0.0049	0.0615	0.0120	0.0014	0.000283	0.00424
Sample Size, n_R	2	2	2	2	2	2
C Mean, $\bar{x}_C$ [a]	0.5530	1.5760	4.3630	0.1765	0.02510	0.08800
C Std. Dev., s_C [a]	0.0028	0.0057	0.0085	0.0007	0.000424	0.00707
Sample Size, n_C	2	2	2	2	2	2
Pooled Std. Dev. Sp[a,b]	0.0040	0.0437	0.0104	0.0012	0.000361	0.00583
Mean Difference [a,c]	0.0265	-0.3465	-0.0755	0.0085	0.021900	0.03700
Degrees of Freedom [d]	2	2	2	2	2	2
Computed "t" [e]	5.574	-7.932	-7.257	7.603	60.740	6.3454
Student "t" (0.95 Conf. Level)	4.303	4.303	4.303	4.303	4.303	4.303
Hypothesis: $\mu_C = \mu_R$ [f]	Reject	Reject	Reject	Reject	Reject	Reject
Statistical Conclusion[g]	**C>R**	**C<R**	**C<R**	**C>R**	**C>R**	**C>R**

CRITERIA AND LIMITATIONS associated with this statistical analysis of the data are described in a paragraph in Section III of this report; that paragraph by reference becomes an integral part of this table.

[a] Units for the Mean, Std. Dev., and Mean Difference are g/hp-hr.

[b] $Sp = \sqrt{[(n_C - 1) S_C^2 + (n_R - 1) S_R^2] / [(n_C - 1) + (n_R - 1)]}$ Pooled std. dev. is provided to show overall deviation of the test results.

[c] Mean Difference = $\bar{x}_C - \bar{x}_R$.

[d] Degrees of Freedom = $n_R + n_C - 2$.

[e] $t = (\bar{x}_C - \bar{x}_R) / \sqrt{(n_C - 1) s_C^2 + (n_R - 1) s_R^2} \times \sqrt{n_C n_R (n_C + n_R - 2) / (n_C + n_R)}$

[f] μ is the population mean (Hypothesis is that at 95 percent confidence level the population mean values for the two sets of test results do not differ).

[g] This conclusion indicates the emission level of candidate fuel relative to the emission level of reference fuel.

TABLE 10. COMPARISON OF TRANSIENT HOT-START EMISSIONS SCREENING TEST CONDUCTED ON A PROTOTYPE 1991 DDC SERIES 60 HEAVY-DUTY DIESEL ENGINE ON REFERENCE FUEL 2D (R) AND A CANDIDATE FUEL C3 (C)

Results of Hot-Start Transient Screening Procedure	HC	CO	NO_x	Part.	Sulfate	SOF
R Mean, $\bar{x}_R$ [a]	0.5548	1.9213	4.3795	0.1738	0.003000	0.05425
R Std. Dev., s_R [a]	0.0231	0.0326	0.0320	0.0028	0.000183	0.00126
Sample Size, n_R	4	4	4	4	4	4
C Mean, $\bar{x}_C$ [a]	0.6298	1.6960	4.3653	0.1533	0.009550	0.06025
C Std. Dev., s_C [a]	0.0129	0.0384	0.0586	0.0057	0.000933	0.00670
Sample Size, n_C	4	4	4	4	4	4
Pooled Std. Dev. Sp[a,b]	0.0187	0.0356	0.0472	0.0045	0.000672	0.00482
Mean Difference [a,c]	0.0750	-0.2253	-0.0143	-0.0205	0.00655	0.00600
Degrees of Freedom [d]	6	6	6	6	6	6
Computed "t" [e]	5.665	-8.950	-4.269	-6.443	13.783	1.7598
Student "t" (0.95 Conf. Level)	2.447	2.447	2.447	2.447	2.447	2.447
Hypothesis: $\mu_C = \mu_R$ [f]	Reject	Reject	Reject	Reject	Reject	Accept
Statistical Conclusion[g]	**C>R**	**C<R**	**C<R**	**C<R**	**C>R**	**C=R**

CRITERIA AND LIMITATIONS associated with this statistical analysis of the data are described in a paragraph in Section III of this report; that paragraph by reference becomes an integral part of this table.

[a] Units for the Mean, Std. Dev., and Mean Difference are g/hp-hr.

[b] $Sp = \sqrt{[(n_C - 1)S_C^2 + (n_R - 1)S_R^2] / [(n_C - 1) + (n_R - 1)]}$ Pooled std. dev. is provided to show overall deviation of the test results.

[c] Mean Difference = $\bar{x}_C - \bar{x}_R$.

[d] Degrees of Freedom = $n_R + n_C - 2$.

[e] $t = (\bar{x}_C - \bar{x}_R) / \sqrt{(n_C - 1)\, s_C^2 + (n_R - 1)\, s_R^2} \times \sqrt{n_C n_R (n_C + n_R - 2) / (n_C + n_R)}$

[f] μ is the population mean (Hypothesis is that at 95 percent confidence level the population mean values for the two sets of test results do not differ).

[g] This conclusion indicates the emission level of candidate fuel relative to the emission level of reference fuel.

TABLE 11. COMPARISON OF TRANSIENT HOT-START EMISSIONS SCREENING TEST CONDUCTED ON A 1990 GM 6.2L HEAVY-DUTY DIESEL ENGINE ON REFERENCE FUEL 2D (R) AND A CANDIDATE FUEL C1 (C)

Results of Hot-Start Transient Screening Procedure	HC	CO	NO_x	Part.	Sulfate	SOF
R Mean, $\bar{x}_R$ [a]	0.4928	1.8948	3.247	0.3048	0.002725	0.10575
R Std. Dev., s_R [a]	0.0292	0.0361	0.0567	0.0114	0.000171	0.00591
Sample Size, n_R	4	4	4	4	4	4
C Mean, $\bar{x}_C$ [a]	0.6398	2.115	3.2168	0.2288	0.00405	0.09250
C Std. Dev., s_C [a]	0.0657	0.0652	0.0449	0.0017	0.000173	0.00551
Sample Size, n_C	4	4	4	4	4	4
Pooled Std. Dev. Sp [a,b]	0.0508	0.0527	0.0511	0.0082	0.000172	0.00571
Mean Difference [a,c]	0.147	0.2203	-0.0303	-0.076	0.001325	-0.0133
Degrees of Freedom [d]	6	6	6	6	6	6
Computed "t" [e]	4.089	5.915	-0.837	-13.172	10.895	-3.2806
Student "t" (0.95 Conf. Level)	2.447	2.447	2.447	2.447	2.447	2.447
Hypothesis: $\mu_C = \mu_R$ [f]	Reject	Reject	Accept	Reject	Reject	Reject
Statistical Conclusion [g]	**C>R**	**C>R**	**C=R**	**C<R**	**C>R**	**C<R**

CRITERIA AND LIMITATIONS associated with this statistical analysis of the data are described in a paragraph in Section III of this report; that paragraph by reference becomes an integral part of this table.

[a] Units for the Mean, Std. Dev., and Mean Difference are g/hp-hr.

[b] $Sp = \sqrt{[(n_C - 1)S_C^2 + (n_R - 1)S_R^2] / [(n_C - 1) + (n_R - 1)]}$ Pooled std. dev. is provided to show overall deviation of the test results.

[c] Mean Difference = $\bar{x}_C - \bar{x}_R$.

[d] Degrees of Freedom = $n_R + n_C - 2$.

[e] $t = (\bar{x}_C - \bar{x}_R) / \sqrt{(n_C - 1)s_C^2 + (n_R - 1)s_R^2} \times \sqrt{n_C n_R (n_C + n_R - 2) / (n_C + n_R)}$

[f] μ is the population mean (Hypothesis is that at 95 percent confidence level the population mean values for the two sets of test results do not differ).

[g] This conclusion indicates the emission level of candidate fuel relative to the emission level of reference fuel.

TABLE 12. COMPARISON OF TRANSIENT HOT-START EMISSIONS SCREENING TEST CONDUCTED ON A 1990 GM 6.2L HEAVY-DUTY DIESEL ENGINE ON REFERENCE FUEL 2D (R) AND A CANDIDATE FUEL C2 (C)

Results of Hot-Start Transient Screening Procedure	HC	CO	NO_x	Part.	Sulfate	SOF
R Mean, $\bar{x}_R$ [a]	0.4265	1.863	3.263	0.2960	0.002900	0.08850
R Std. Dev., s_R [a]	0.0912	0.1216	0.0297	0.0127	0.000424	0.00212
Sample Size, n_R	2	2	2	2	2	2
C Mean, $\bar{x}_C$ [a]	0.4115	1.7545	3.240	0.2715	0.02165	0.11450
C Std. Dev., s_C [a]	0.0106	0.0615	0.0170	0.0035	0.000354	0.00212
Sample Size, n_C	2	2	2	2	2	2
Pooled Std. Dev. Sp[a,b]	0.0649	0.0964	0.0242	0.0093	0.000391	0.00212
Mean Difference [a,c]	-0.015	-0.1085	-0.0230	-0.0245	0.01875	0.0260
Degrees of Freedom [d]	2	2	2	2	2	2
Computed "t" [e]	-2.310	-1.126	-0.951	-2.623	48.014	-12.2565
Student "t" (0.95 Conf. Level)	4.303	4.303	4.303	4.303	4.303	4.303
Hypothesis: $\mu_C = \mu_R$ [f]	Accept	Accept	Accept	Accept	Reject	Reject
Statistical Conclusion[g]	**C=R**	**C=R**	**C=R**	**C=R**	**C>R**	**C>R**

CRITERIA AND LIMITATIONS associated with this statistical analysis of the data are described in a paragraph in Section III of this report; that paragraph by reference becomes an integral part of this table.

[a] Units for the Mean, Std. Dev., and Mean Difference are g/hp-hr.

[b] $Sp = \sqrt{[(n_C-1)S_C^2 + (n_R-1)S_R^2] / [(n_C-1) + (n_R-1)]}$ Pooled std. dev. is provided to show overall deviation of the test results.

[c] Mean Difference = $\bar{x}_C - \bar{x}_R$.

[d] Degrees of Freedom = $n_R + n_C - 2$.

[e] $t = (\bar{x}_C - \bar{x}_R) / \sqrt{(n_C - 1) s_C^2 + (n_R - 1) s_R^2} \times \sqrt{n_C n_R (n_C + n_R - 2) / (n_C + n_R)}$

[f] μ is the population mean (Hypothesis is that at 95 percent confidence level the population mean values for the two sets of test results do not differ).

[g] This conclusion indicates the emission level of candidate fuel relative to the emission level of reference fuel.

TABLE 13. COMPARISON OF TRANSIENT HOT-START EMISSIONS SCREENING TEST CONDUCTED ON A 1990 GM 6.2L HEAVY-DUTY DIESEL ENGINE ON REFERENCE FUEL 2D (R) AND A CANDIDATE FUEL C3 (C)

Results of Hot-Start Transient Screening Procedure	HC	CO	NO_x	Part.	Sulfate	SOF
R Mean, $\bar{x}_R$ [a]	0.4290	1.7293	3.2513	0.2735	0.002775	0.08250
R Std. Dev., s_R [a]	0.0334	0.0792	0.0825	0.0087	0.000126	0.00915
Sample Size, n_R	4	4	4	4	4	4
C Mean, $\bar{x}_C$ [a]	0.4363	1.7718	3.2420	0.2283	0.0096	0.08225
C Std. Dev., s_C [a]	0.0163	0.0703	0.0160	0.0039	0.001	0.01090
Sample Size, n_C	4	4	4	3	4	4
Pooled Std. Dev. Sp[a,b]	0.0263	0.0749	0.0647	0.0067	0.000713	0.01006
Mean Difference [a,c]	0.0073	0.0425	-0.0093	-0.0453	0.006825	-0.0003
Degrees of Freedom [d]	6	6	6	5	6	6
Computed "t" [e]	0.390	0.802	-0.187	-9.509	13.543	-0.0351
Student "t" (0.95 Conf. Level)	2.447	2.447	2.447	2.447	2.447	2.447
Hypothesis: $\mu_C = \mu_R$ [f]	Accept	Accept	Accept	Reject	Reject	Accept
Statistical Conclusion[g]	**C=R**	**C=R**	**C=R**	**C<R**	**C>R**	**C=R**

CRITERIA AND LIMITATIONS associated with this statistical analysis of the data are described in a paragraph in Section III of this report; that paragraph by reference becomes an integral part of this table.

[a] Units for the Mean, Std. Dev., and Mean Difference are g/hp-hr.

[b] $Sp = \sqrt{[(n_C-1)S_C^2 + (n_R-1)S_R^2] / [(n_C-1) + (n_R-1)]}$ Pooled std. dev. is provided to show overall deviation of the test results.

[c] Mean Difference = $\bar{x}_C - \bar{x}_R$.

[d] Degrees of Freedom = $n_R + n_C - 2$.

[e] $t = (\bar{x}_C - \bar{x}_R) / \sqrt{(n_C - 1)s_C^2 + (n_R - 1)s_R^2} \times \sqrt{n_C n_R (n_C + n_R - 2) / (n_C + n_R)}$

[f] μ is the population mean (Hypothesis is that at 95 percent confidence level the population mean values for the two sets of test results do not differ).

[g] This conclusion indicates the emission level of candidate fuel relative to the emission level of reference fuel.

$$t = \frac{x_C - x_R}{\sqrt{(n_C - 1)s_C^2 + (n_R - 1)s_R^2}}\sqrt{\frac{n_C n_R(n_C + n_R - 2)}{n_C + n_R}}$$

Where $\bar{x}_C$ and $\bar{x}_R$ are the mean values of emissions for C (as applicable to Fuels C1, C2, and C3) and R (Fuel 2D), respectively; and where n_C and n_R are the number of tests for each fuel, and S_C and S_R are standard deviations for each set of data for the corresponding fuel tested.

The statistical conclusions of the hypothesis tests given in Tables 8 through 13, indicate if the respective R and C emission means for Fuels 2D, C1, C2, and C3 are either **Equal (Fuel C is equal to Fuel R)** or **Not Equal (Fuel C is either lower or higher than Fuel R)**. These "conclusions" are summarized in Table 14 for easier review. Based on the Series 60 results, the JP-8 fuels provided significantly lower average emissions than the 2D fuel for CO using Fuels C1, C2, and C3, for NO_x using Fuels C2 and C3, for PM using Fuels C1 and C3, and for SOF using Fuel C1. JP-8 fuels having average emissions equivalent to 2D fuel were Fuel C1 for HC and NO_x, and Fuel C3 for SOF. JP-8 fuels having significantly higher average emissions than the 2D fuel were C1 for sulfate, C2 for HC, PM, sulfate, and SOF, and C3 for HC and sulfate.

From test results of hot-start transient evaluations of fuels completed with the 1990 GM 6.2L engine, JP-8 fuels producing significantly lower average emissions than the 2-D fuel were Fuel C1 for PM and SOF, and Fuel C3 for PM. Equivalence to 2D fuel average emissions was demonstrated for Fuel C1 for NO_x, Fuel C2 for HC, CO, NO_x, and PM, and Fuel C3 for HC, CO, NO_x, and SOF. JP-8 fuels that had higher average emissions than the 2D fuel were Fuel C1 for HC, CO, and sulfate, Fuel C2 for sulfate and SOF, and Fuel C3 for sulfate.

TABLE 14. STATISTICAL CONCLUSIONS

Test Fuel ID	Statistical Conclusion to the Hypothesis that C = R[a]					
	HC	CO	NO_x	PM	Sulfate	SOF
1991 Prototype DDC Series 60 Engine						
C1	**C = R**	C<R	**C = R**	C<R	C>R	C<R
C2	C>R	C<R	C<R	C>R	C>R	C>R
C3	C>R	C<R	C<R	C<R	C>R	**C = R**
1990 GM 6.2L Engine						
C1	C>R	C>R	**C = R**	C<R	C>R	C<R
C2	**C = R**	**C = R**	**C = R**	**C = R**	C>R	C>R
C3	**C = R**	**C = R**	**C = R**	C<R	C>R	**C = R**

[a]This conclusion indicates the emission level of candidate Fuel C relative to the emission level of reference Fuel R. Bold-faced conclusions are where emissions on C were equivalent to emissions on R.

APPENDIX A

FUEL SPECIFICATIONS FOR FUELS 2D, C1, C2, AND C3

DEPARTMENT OF EMISSIONS RESEARCH

1994 CERTIFICATION DIESEI FUEL SPECIFICATIONS

FUEL TYPE 1-D ______ 2-D X SUPPLIER PHILLIPS 66

LOT NO. S-288 SwRI CODE EM-1749-F

Item	CFR Specification[a]			Supplier Analysis	SwRI Analysis
	ASTM	Type 1-D	Type 2-D		
Cetane Number	D613	40-54	40-48	46.0	45.8
Cetane Index	D976	40-54	40-48	47.3	46.6
Distillation Range:					
IBP°F	D86	330-390	340-400	366	361
10% Point, °F	D86	370-430	400-460	438	435
50% Point, °F	D86	410-480	470-540	512	509
90% Point, °F	D86	460-520	560-630	593	593
EP, °F	D86	500-560	610-690	640	639
Gravity, API	D287	40-44	32-37	35.1	35.3
Total Sulfur, %	D2622	0.03-0.05	0.03-0.05	0.035	0.035
Hydrocarbon Composition:					
Aromatics, %	D1319	8[b]	27[b]	29.7	31.4
Paraffins, Naphthenes, Olefins	D1319	c	c	70.3	68.6
Flashpoint, °F	D93	120 (min.)	130 (min.)	189	169
Viscosity, Centistokes	D445	1.6-2.0	2.2-3.4	2.98	2.71

[a]Diesel fuel specification as in CFR 86.113-94(b)(2) for light-duty diesel vehicles and CFR 86.1313-94(b)(2) for heavy-duty diesel engines.
[b]Minimum
[c]Remainder

SwRI Analysis
by: Becky Riddle
Date: 3-22-94

TABLE X. KEROSENE TYPE JP-8 FUEL PROPERTIES UTILIZED FOR HOT-START TRANSIENT EMISSION EVALUATIONS

Item	ASTM	Analysis		
Cetane Number	D 613		45.5	
Distillation Range:				
IBP°F	D 86		324	
10% Point, °F	D 86		363	
50% Point, °F	D 86		399	
90% Point, °F	D 86		446	
EP, °F	D 86		486	
Density @ 15°C, kg/L	D 1298		0.8073	
Total Sulfur, mass%	D 4294	0.06[a]	0.11[b]	0.26[c]
Carbon, mass%	D 5291		86.08	
Hydrogen, mass%	D 5291		13.76	
Hydrocarbon Composition:				
Aromatics, wt%	D 5186		20.5	
Viscosity @ 40°C, cSt	D 445		1.32	
Net Heat of Combustion:				
MJ/kg	D 240		43.05	
Btu/lb	D 240		18506	

[a]EM-1809-F: neat fuel received from Kelly AFB, San Antonio, TX.
[b]EM-1818-F: 99.86 vol% EM-1809-F + 0.14 vol% DTBS.
[c]EM-1816-F: 99.44 vol% EM-1809-F + 0.56 vol% DTBS.

APPENDIX B

STATEMENT OF PRECISION AND ACCURACY

VII. PROCEDURE TO ASSESS DATA PRECISION AND ACCURACY

In general, results from emissions testing on a selected fuel are expected to have a precision or standard deviation within the levels given in Table VII-1. Sometimes the precision of the results fall outside these expected targets for repeatability through no directly traceable fault. All test results are generally reviewed for integrity. Test results that appear to vary more than expected are closely scrutinized for errors, maladjustments, malfunctions, or use of procedural operations outside the limits established by federal test procedures. If problems or errors are noted, the results are voided and the test repeated when possible. If no fault is found and procedural limits have not been exceeded, the test results are deemed representative of the configuration tested and are accepted.

TABLE VII-1. ESTIMATED PRECISION AND ACCURACY FOR COLD AND HOT TRANSIENT RESULTS

Transient Emission Measurement	Test Type	Precision, Std. Dev., g/hp-hr	Expected Range of Emission, g/hp-hr[d,f]	Estimated Accuracy, %
HC	Cold	0.05[a]	0.18 - 0.56	±20
	Hot	0.04[a]	0.16 - 0.94	±20
CO	Cold	0.10[a]	1.4 - 2.6	±15
	Hot	0.10[a]	1.2 - 2.7	±15
NO_x	Cold	0.18[a]	5.5 - 7.0	±10
	Hot	0.14[a]	4.0 - 5.0	±10
Total Part.	Cold	0.03[a]	0.12 - 0.20	±20
	Hot	0.03[a]	0.15 - 0.25	±20
Sulfate	Cold	0.002[b,c]	0.003 - 0.007[e]	±25
	Hot	0.002[b,c]	0.003 - 0.007[e]	±25
SOF	Cold	0.025[c,d]	0.025 - 0.100	±30
	Hot	0.025[c,d]	0.020 - 0.110	±30

[a]Values based on observed standard deviations for CRC VE-1 emissions test work.
[b]Using low sulfur fuel containing approximately 0.05 percent weight sulfur.
[c]Values based on observed standard deviation from limited analysis of total particulate collected under CRC VE-1 program on behalf of WSPA.
[d]SOF extracted with toluene/ethanol.
[e]Range of values using several fuels with a DDC Series 60 engine during CRC VE-1 project.
[f]Range of emissions may vary according to type of fuel used.

APPENDIX C

REFERENCE AND CANDIDATE FUELS HOT-START TRANSIENT EMISSIONS OBTAINED ON PROTOTYPE 1991 DDC SERIES 60 HEAVY-DUTY DIESEL ENGINE

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER PROTO
ENGINE MODEL 91 DD SERIES 60
ENGINE 11.1 L(677. CID) I-6
ENGINE CYCLE DIESEL

TEST R06084A RUN
DATE 6/ 8/94 TIME 10:10
COMPUTER PROGRAM HDT 3.1-R
CELL 7 BAG CART 1

DIESEL 2D EM-1749-F
HCR 1.79 FID RES. FAC. 1.000
H .130 C .870 O .000 X .000
ENGINE OIL

BAROMETER 738.4 MM HG (29.07 IN HG)
ENGINE AIR TEMP. 27.2°C (81.0°F)

CVS: 76.0°F RH 63.0 PCT AH 87.3 GR/LB
ENGINE ABS. HUM. 11.0 G/KG (77.3 GR/LB)

ENGINE DEW PT. 15.1°C (59.1°F)
NOX HUMIDITY C.F. 1.006
DRY-TO-WET C.F. .975

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1206.5
TOT. BLOWER RATE SCMM (SCFM)	62.76 (2216.1)
TOT. 90MM RATE SCMM (SCFM)	.06 (2.01)
TOT. 20X20 RATE SCMM (SCFM)	1.81 (63.9)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.09 (3.30)
TOTAL FLOW STD. CU. METRES(SCF)	1301.4 (45954.)
HC SAMPLE METER/RANGE/PPM	.3/ 76/ 21.03
HC BCKGRD METER/RANGE/PPM	.1/ 76/ 6.63
CO SAMPLE METER/RANGE/PPM	32.7/ 13/ 29.85
CO BCKGRD METER/RANGE/PPM	.5/ 13/ .44
CO2 SAMPLE METER/RANGE/PCT	69.2/ 11/ .5787
CO2 BCKGRD METER/RANGE/PCT	7.9/ 11/ .0464
NOX SAMPLE METER/RANGE/PPM (D)	.5/ 73/ 41.38
NOX BCKGRD METER/RANGE/PPM	.2/ 2/ .21
DILUTION FACTOR	23.37
HC CONCENTRATION PPM	14.68
CO CONCENTRATION PPM	28.51
CO2 CONCENTRATION PCT	.5342
NOX CONCENTRATION PPM	40.15
HC MASS GRAMS	10.968
CO MASS GRAMS	43.189
CO2 MASS GRAMS	12719.58
NOX MASS GRAMS	100.526
FUEL KG (LB)	4.025 (8.87)
KW HR (HP HR)	16.75 (22.46)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.655(.488) (.49) (CONT)
BSCO G/KW HR (G/HP HR)	2.579(1.923) (1.92)
BSNOX G/KW HR (G/HP HR)	6.002(4.476) (4.48) (CONT)
PART. G/KW HR (G/HP HR)	.227(.169) (.17)
BSFC KG/KW HR (LB/HP HR)	.240(.395)
WORK KW HR (HP HR)	16.75(22.46)
BSCO2 G/KW HR (G/HP HR)	759. (566.)

90 MM FILTER NUMBERS	P90-1	P90-2
90 MM FILTER WT. GAINS (MG)	3.113	.231
PARTICULATE GRAMS/TEST	3.794	

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EPA HOT-TRANS ENGINE EMISSION RESULTS

PROJECT NO. 02-5137-506

ENGINE NUMBER PROTO
ENGINE MODEL 91 DD SERIES 60
ENGINE 11.1 L(677. CID) I-6
ENGINE CYCLE DIESEL

TEST C106084A RUN
DATE 6/ 8/94 TIME 12:45
COMPUTER PROGRAM HDT 3.1-R
CELL 7 BAG CART 1

DIESEL 2D EM-1809-F
HCR 1.90 FID RES. FAC. 1.000
H .138 C .862 O .000 X .000
ENGINE OIL

BAROMETER 738.4 MM HG (29.07 IN HG)
ENGINE AIR TEMP. 27.8°C (82.0°F)

CVS: 76.0°F RH 63.0 PCT AH 87.3 GR/LB
ENGINE ABS. HUM. 11.2 G/KG (78.2 GR/LB)

ENGINE DEW PT. 15.2°C (59.4°F)
NOX HUMIDITY C.F. 1.008
DRY-TO-WET C.F. .975

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1206.5
TOT. BLOWER RATE SCMM (SCFM)	62.66 (2212.4)
TOT. 90MM RATE SCMM (SCFM)	.06 (2.01)
TOT. 20X20 RATE SCMM (SCFM)	1.87 (66.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.09 (3.30)
TOTAL FLOW STD. CU. METRES(SCF)	1300.5 (45921.)
HC SAMPLE METER/RANGE/PPM	.3/ 76/ 21.09
HC BCKGRD METER/RANGE/PPM	.1/ 76/ 5.33
CO SAMPLE METER/RANGE/PPM	26.6/ 13/ 24.07
CO BCKGRD METER/RANGE/PPM	.1/ 13/ .09
CO2 SAMPLE METER/RANGE/PCT	66.9/ 11/ .5524
CO2 BCKGRD METER/RANGE/PCT	7.7/ 11/ .0452
NOX SAMPLE METER/RANGE/PPM (D)	.5/ 73/ 40.92
NOX BCKGRD METER/RANGE/PPM	.7/ 2/ .73
DILUTION FACTOR	23.95
HC CONCENTRATION PPM	15.98
CO CONCENTRATION PPM	23.24
CO2 CONCENTRATION PCT	.5092
NOX CONCENTRATION PPM	39.20
HC MASS GRAMS	12.031
CO MASS GRAMS	35.185
CO2 MASS GRAMS	12113.70
NOX MASS GRAMS	98.297
FUEL KG (LB)	3.864 (8.52)
KW HR (HP HR)	16.44 (22.04)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.732(.546) (.55) (CONT)
BSCO G/KW HR (G/HP HR)	2.141(1.596) (1.60)
BSNOX G/KW HR (G/HP HR)	5.981(4.460) (4.46) (CONT)
PART. G/KW HR (G/HP HR)	.180(.134) (.13)
BSFC KG/KW HR (LB/HP HR)	.235(.387)
WORK KW HR (HP HR)	16.44(22.04)
BSCO2 G/KW HR (G/HP HR)	737. (550.)

90 MM FILTER NUMBERS	P90-3	P90-4
90 MM FILTER WT. GAINS (MG)	2.428	.182
PARTICULATE GRAMS/TEST	2.958	

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EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER PROTO	TEST C106084B RUN	DIESEL 2D EM-1809-F
ENGINE MODEL 91 DD SERIES 60	DATE 6/ 8/94 TIME 1:25	HCR 1.90 FID RES. FAC. 1.000
ENGINE 11.1 L(677. CID) I-6	COMPUTER PROGRAM HDT 3.1-R	H .138 C .862 O .000 X .000
ENGINE CYCLE DIESEL	CELL 7 BAG CART 1	ENGINE OIL

BAROMETER 738.1 MM HG (29.06 IN HG)	CVS: 76.0°F RH 63.0 PCT AH 87.3 GR/LB	ENGINE DEW PT. 15.2°C (59.4°F)
ENGINE AIR TEMP. 27.8°C (82.0°F)	ENGINE ABS. HUM. 11.2 G/KG (78.2 GR/LB)	NOX HUMIDITY C.F. 1.008
		DRY-TO-WET C.F. .975

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1207.2
TOT. BLOWER RATE SCMM (SCFM)	62.63 (2211.5)
TOT. 90MM RATE SCMM (SCFM)	.06 (2.01)
TOT. 20X20 RATE SCMM (SCFM)	1.86 (65.5)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.09 (3.33)
TOTAL FLOW STD. CU. METRES(SCF)	1300.5 (45921.)
HC SAMPLE METER/RANGE/PPM	.2/ 76/ 20.88
HC BCKGRD METER/RANGE/PPM	.1/ 76/ 5.35
CO SAMPLE METER/RANGE/PPM	27.4/ 13/ 24.82
CO BCKGRD METER/RANGE/PPM	.8/ 13/ .70
CO2 SAMPLE METER/RANGE/PCT	67.3/ 11/ .5570
CO2 BCKGRD METER/RANGE/PCT	7.7/ 11/ .0452
NOX SAMPLE METER/RANGE/PPM (D)	.5/ 73/ 41.78
NOX BCKGRD METER/RANGE/PPM	.3/ 2/ .31
DILUTION FACTOR	23.76
HC CONCENTRATION PPM	15.76
CO CONCENTRATION PPM	23.39
CO2 CONCENTRATION PCT	.5137
NOX CONCENTRATION PPM	40.43
HC MASS GRAMS	11.860
CO MASS GRAMS	35.416
CO2 MASS GRAMS	12221.58
NOX MASS GRAMS	101.399
FUEL KG (LB)	3.898 (8.59)
KW HR (HP HR)	16.32 (21.88)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.727(.542) (.54) (CONT)
BSCO G/KW HR (G/HP HR)	2.171(1.619) (1.62)
BSNOX G/KW HR (G/HP HR)	6.215(4.634) (4.63) (CONT)
PART. G/KW HR (G/HP HR)	.175(.130) (.13)
BSFC KG/KW HR (LB/HP HR)	.239(.393)
WORK KW HR (HP HR)	16.32(21.88)
BSCO2 G/KW HR (G/HP HR)	749. (559.)

90 MM FILTER NUMBERS	P90-5	P90-6
90 MM FILTER WT. GAINS (MG)	2.354	.153
PARTICULATE GRAMS/TEST	2.847	

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EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER PROTO	TEST R06084B RUN	DIESEL 2D EM-1749-F
ENGINE MODEL 91 DD SERIES 60	DATE 6/ 8/94 TIME 3:45	HCR 1.79 FID RES. FAC. 1.000
ENGINE 11.1 L(677. CID) I-6	COMPUTER PROGRAM HDT 3.1-R	H .130 C .870 O .000 X .000
ENGINE CYCLE DIESEL	CELL 7 BAG CART 1	ENGINE OIL

BAROMETER 737.1 MM HG (29.02 IN HG)	CVS: 76.0°F RH 63.0 PCT AH 87.5 GR/LB	ENGINE DEW PT. 15.8°C (60.5°F)
ENGINE AIR TEMP. 28.3°C (83.0°F)	ENGINE ABS. HUM. 11.6 G/KG (81.5 GR/LB)	NOX HUMIDITY C.F. 1.017
		DRY-TO-WET C.F. .975

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1206.9
TOT. BLOWER RATE SCMM (SCFM)	62.54 (2208.3)
TOT. 90MM RATE SCMM (SCFM)	.06 (2.01)
TOT. 20X20 RATE SCMM (SCFM)	1.85 (65.5)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.09 (3.31)
TOTAL FLOW STD. CU. METRES(SCF)	1298.3 (45844.)
HC SAMPLE METER/RANGE/PPM	.2/ 76/ 20.04
HC BCKGRD METER/RANGE/PPM	.1/ 76/ 4.41
CO SAMPLE METER/RANGE/PPM	32.5/ 13/ 29.66
CO BCKGRD METER/RANGE/PPM	.3/ 13/ .26
CO2 SAMPLE METER/RANGE/PCT	69.2/ 11/ .5787
CO2 BCKGRD METER/RANGE/PCT	7.7/ 11/ .0452
NOX SAMPLE METER/RANGE/PPM (D)	.5/ 73/ 41.20
NOX BCKGRD METER/RANGE/PPM	.2/ 2/ .21
DILUTION FACTOR	23.38
HC CONCENTRATION PPM	15.82
CO CONCENTRATION PPM	28.48
CO2 CONCENTRATION PCT	.5354
NOX CONCENTRATION PPM	39.97
HC MASS GRAMS	11.788
CO MASS GRAMS	43.053
CO2 MASS GRAMS	12717.07
NOX MASS GRAMS	100.944
FUEL KG (LB)	4.025 (8.87)
KW HR (HP HR)	16.77 (22.49)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.703(.524) (.52) (CONT)	90 MM FILTER NUMBERS	P90-7	P90-8
BSCO G/KW HR (G/HP HR)	2.567(1.914) (1.91)	90 MM FILTER WT. GAINS (MG)	3.094	.200
BSNOX G/KW HR (G/HP HR)	6.019(4.488) (4.49) (CONT)	PARTICULATE GRAMS/TEST	3.743	
PART. G/KW HR (G/HP HR)	.223(.166) (.17)			
BSFC KG/KW HR (LB/HP HR)	.240(.395)			
WORK KW HR (HP HR)	16.77(22.49)			
BSCO2 G/KW HR (G/HP HR)	758. (565.)			

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EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER PROTO	TEST R06094A RUN	DIESEL 2D EM-1749-F
ENGINE MODEL 91 DD SERIES 60	DATE 6/ 9/94 TIME 9:15	HCR 1.79 FID RES. FAC. 1.000
ENGINE 11.1 L(677. CID) I-6	COMPUTER PROGRAM HDT 3.1-R	H .130 C .870 O .000 X .000
ENGINE CYCLE DIESEL	CELL 7 BAG CART 1	ENGINE OIL

BAROMETER 740.2 MM HG (29.14 IN HG)	CVS: 73.0°F RH 65.0 PCT AH 81.8 GR/LB	ENGINE DEW PT. 15.2°C (59.3°F)
ENGINE AIR TEMP. 25.6°C (78.0°F)	ENGINE ABS. HUM. 11.1 G/KG (77.7 GR/LB)	NOX HUMIDITY C.F. 1.007
		DRY-TO-WET C.F. .976

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1206.8
TOT. BLOWER RATE SCMM (SCFM)	62.92 (2221.8)
TOT. 90MM RATE SCMM (SCFM)	.06 (2.04)
TOT. 20X20 RATE SCMM (SCFM)	1.81 (64.1)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.09 (3.33)
TOTAL FLOW STD. CU. METRES(SCF)	1305.1 (46084.)
HC SAMPLE METER/RANGE/PPM	.2/ 76/ 20.10
HC BCKGRD METER/RANGE/PPM	.1/ 76/ 5.25
CO SAMPLE METER/RANGE/PPM	33.1/ 13/ 30.23
CO BCKGRD METER/RANGE/PPM	1.0/ 13/ .87
CO2 SAMPLE METER/RANGE/PCT	69.6/ 11/ .5833
CO2 BCKGRD METER/RANGE/PCT	9.0/ 11/ .0532
NOX SAMPLE METER/RANGE/PPM (D)	.5/ 73/ 40.86
NOX BCKGRD METER/RANGE/PPM	.5/ 2/ .52
DILUTION FACTOR	23.19
HC CONCENTRATION PPM	15.08
CO CONCENTRATION PPM	28.44
CO2 CONCENTRATION PCT	.5323
NOX CONCENTRATION PPM	39.39
HC MASS GRAMS	11.294
CO MASS GRAMS	43.212
CO2 MASS GRAMS	12710.24
NOX MASS GRAMS	99.010
FUEL KG (LB)	4.022 (8.87)
KW HR (HP HR)	16.73 (22.43)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.675(.504) (.50) (CONT)	90 MM FILTER NUMBERS	P90-9	P90-10
BSCO G/KW HR (G/HP HR)	2.584(1.927) (1.93)	90 MM FILTER WT. GAINS (MG)	3.075	.182
BSNOX G/KW HR (G/HP HR)	5.919(4.414) (4.41) (CONT)	PARTICULATE GRAMS/TEST	3.663	
PART. G/KW HR (G/HP HR)	.219(.163) (.16)			
BSFC KG/KW HR (LB/HP HR)	.240(.395)			
WORK KW HR (HP HR)	16.73(22.43)			
BSCO2 G/KW HR (G/HP HR)	760. (567.)			

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EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER PROTO	TEST C106094A RUN	DIESEL 2D EM-1809-F
ENGINE MODEL 91 DD SERIES 60	DATE 6/ 9/94 TIME 1:05	HCR 1.90 FID RES. FAC. 1.000
ENGINE 11.1 L(677. CID) I-6	COMPUTER PROGRAM HDT 3.1-R	H .138 C .862 O .000 X .000
ENGINE CYCLE DIESEL	CELL 7 BAG CART 1	ENGINE OIL

BAROMETER 739.9 MM HG (29.13 IN HG)	CVS: 76.0°F RH 67.0 PCT AH 92.4 GR/LB	ENGINE DEW PT. 15.3°C (59.5°F)
ENGINE AIR TEMP. 25.6°C (78.0°F)	ENGINE ABS. HUM. 11.2 G/KG (78.3 GR/LB)	NOX HUMIDITY C.F. 1.009
		DRY-TO-WET C.F. .974

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1206.6
TOT. BLOWER RATE SCMM (SCFM)	62.76 (2215.9)
TOT. 90MM RATE SCMM (SCFM)	.06 (2.03)
TOT. 20X20 RATE SCMM (SCFM)	1.86 (65.6)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.09 (3.30)
TOTAL FLOW STD. CU. METRES(SCF)	1302.4 (45988.)
HC SAMPLE METER/RANGE/PPM	.3/ 76/ 22.62
HC BCKGRD METER/RANGE/PPM	.1/ 76/ 6.72
CO SAMPLE METER/RANGE/PPM	27.3/ 13/ 24.73
CO BCKGRD METER/RANGE/PPM	.3/ 13/ .26
CO2 SAMPLE METER/RANGE/PCT	67.1/ 11/ .5547
CO2 BCKGRD METER/RANGE/PCT	7.7/ 11/ .0452
NOX SAMPLE METER/RANGE/PPM (D)	.5/ 73/ 40.48
NOX BCKGRD METER/RANGE/PPM	.4/ 2/ .42
DILUTION FACTOR	23.84
HC CONCENTRATION PPM	16.18
CO CONCENTRATION PPM	23.68
CO2 CONCENTRATION PCT	.5114
NOX CONCENTRATION PPM	39.02
HC MASS GRAMS	12.199
CO MASS GRAMS	35.908
CO2 MASS GRAMS	12185.40
NOX MASS GRAMS	98.024
FUEL KG (LB)	3.887 (8.57)
KW HR (HP HR)	16.53 (22.17)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.738(.550) (.55) (CONT)	
BSCO G/KW HR (G/HP HR)	2.172(1.620) (1.62)	
BSNOX G/KW HR (G/HP HR)	5.929(4.421) (4.42) (CONT)	
PART. G/KW HR (G/HP HR)	.175(.131) (.13)	
BSFC KG/KW HR (LB/HP HR)	.235(.387)	
WORK KW HR (HP HR)	16.53(22.17)	
BSCO2 G/KW HR (G/HP HR)	737. (550.)	

90 MM FILTER NUMBERS	P90-11	P90-12
90 MM FILTER WT. GAINS (MG)	2.411	.151
PARTICULATE GRAMS/TEST	2.893	

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EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER PROTO	TEST C106094B RUN	DIESEL 2D EM-1809-F
ENGINE MODEL 91 DD SERIES 60	DATE 6/ 9/94 TIME 1:45	HCR 1.90 FID RES. FAC. 1.000
ENGINE 11.1 L(677. CID) I-6	COMPUTER PROGRAM HDT 3.1-R	H .138 C .862 O .000 X .000
ENGINE CYCLE DIESEL	CELL 7 BAG CART 1	ENGINE OIL

BAROMETER 739.6 MM HG (29.12 IN HG)	CVS: 77.0°F RH 63.0 PCT AH 90.8 GR/LB	ENGINE DEW PT. 15.2°C (59.4°F)
ENGINE AIR TEMP. 26.1°C (79.0°F)	ENGINE ABS. HUM. 11.1 G/KG (78.0 GR/LB)	NOX HUMIDITY C.F. 1.008
		DRY-TO-WET C.F. .974

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1206.2
TOT. BLOWER RATE SCMM (SCFM)	62.77 (2216.4)
TOT. 90MM RATE SCMM (SCFM)	.06 (2.01)
TOT. 20X20 RATE SCMM (SCFM)	1.85 (65.3)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.09 (3.28)
TOTAL FLOW STD. CU. METRES(SCF)	1302.1 (45978.)
HC SAMPLE METER/RANGE/PPM	.3/ 76/ 22.15
HC BCKGRD METER/RANGE/PPM	.1/ 76/ 5.88
CO SAMPLE METER/RANGE/PPM	27.3/ 13/ 24.73
CO BCKGRD METER/RANGE/PPM	.0/ 13/ .00
CO2 SAMPLE METER/RANGE/PCT	67.1/ 11/ .5547
CO2 BCKGRD METER/RANGE/PCT	7.7/ 11/ .0452
NOX SAMPLE METER/RANGE/PPM (D)	.5/ 73/ 40.93
NOX BCKGRD METER/RANGE/PPM	.3/ 2/ .31
DILUTION FACTOR	23.85
HC CONCENTRATION PPM	16.52
CO CONCENTRATION PPM	23.95
CO2 CONCENTRATION PCT	.5114
NOX CONCENTRATION PPM	39.57
HC MASS GRAMS	12.448
CO MASS GRAMS	36.312
CO2 MASS GRAMS	12182.53
NOX MASS GRAMS	99.323
FUEL KG (LB)	3.887 (8.57)
KW HR (HP HR)	16.44 (22.05)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.757(.565) (.56) (CONT)
BSCO G/KW HR (G/HP HR)	2.208(1.647) (1.65)
BSNOX G/KW HR (G/HP HR)	6.041(4.504) (4.50) (CONT)
PART. G/KW HR (G/HP HR)	.179(.133) (.13)
BSFC KG/KW HR (LB/HP HR)	.236(.389)
WORK KW HR (HP HR)	16.44(22.05)
BSCO2 G/KW HR (G/HP HR)	741. (552.)

90 MM FILTER NUMBERS	P90-13	P90-14
90 MM FILTER WT. GAINS (MG)	2.425	.160
PARTICULATE GRAMS/TEST	2.936	

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER PROTO	TEST R06094B RUN	DIESEL 2D EM-1749-F
ENGINE MODEL 91 DD SERIES 60	DATE 6/ 9/94 TIME 4:00	HCR 1.79 FID RES. FAC. 1.000
ENGINE 11.1 L(677. CID) I-6	COMPUTER PROGRAM HDT 3.1-R	H .130 C .870 O .000 X .000
ENGINE CYCLE DIESEL	CELL 7 BAG CART 1	ENGINE OIL

BAROMETER 738.6 MM HG (29.08 IN HG)	CVS: 77.0°F RH 60.0 PCT AH 85.6 GR/LB	ENGINE DEW PT. 15.0°C (59.0°F)
ENGINE AIR TEMP. 26.1°C (79.0°F)	ENGINE ABS. HUM. 11.0 G/KG (77.0 GR/LB)	NOX HUMIDITY C.F. 1.005
		DRY-TO-WET C.F. .975

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1206.3
TOT. BLOWER RATE SCMM (SCFM)	62.64 (2211.9)
TOT. 90MM RATE SCMM (SCFM)	.06 (2.02)
TOT. 20X20 RATE SCMM (SCFM)	1.85 (65.2)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.09 (3.29)
TOTAL FLOW STD. CU. METRES(SCF)	1299.6 (45889.)
HC SAMPLE METER/RANGE/PPM	.3/ 76/ 21.26
HC BCKGRD METER/RANGE/PPM	.1/ 76/ 4.63
CO SAMPLE METER/RANGE/PPM	33.1/ 13/ 30.23
CO BCKGRD METER/RANGE/PPM	.1/ 13/ .09
CO2 SAMPLE METER/RANGE/PCT	68.8/ 11/ .5741
CO2 BCKGRD METER/RANGE/PCT	8.1/ 11/ .0476
NOX SAMPLE METER/RANGE/PPM (D)	.5/ 73/ 40.69
NOX BCKGRD METER/RANGE/PPM	.6/ 2/ .62
DILUTION FACTOR	23.56
HC CONCENTRATION PPM	16.83
CO CONCENTRATION PPM	29.24
CO2 CONCENTRATION PCT	.5284
NOX CONCENTRATION PPM	39.10
HC MASS GRAMS	12.551
CO MASS GRAMS	44.236
CO2 MASS GRAMS	12563.71
NOX MASS GRAMS	97.673
FUEL KG (LB)	3.978 (8.77)
KW HR (HP HR)	16.71 (22.41)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.751(.560) (.56) (CONT)	
BSCO G/KW HR (G/HP HR)	2.647(1.974) (1.97)	
BSNOX G/KW HR (G/HP HR)	5.845(4.358) (4.36) (CONT)	
PART. G/KW HR (G/HP HR)	.225(.168) (.17)	
BSFC KG/KW HR (LB/HP HR)	.238(.391)	
WORK KW HR (HP HR)	16.71(22.41)	
BSCO2 G/KW HR (G/HP HR)	752. (561.)	

90 MM FILTER NUMBERS	P90-15	P90-16
90 MM FILTER WT. GAINS (MG)	3.138	.189
PARTICULATE GRAMS/TEST	3.757	

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER PROTO	TEST R06104A RUN	DIESEL 2D EM-1749-F
ENGINE MODEL 91 DD SERIES 60	DATE 6/10/94 TIME 9:15	HCR 1.79 FID RES. FAC. 1.000
ENGINE 11.1 L(677. CID) I-6	COMPUTER PROGRAM HDT 3.1-R	H .130 C .870 O .000 X .000
ENGINE CYCLE DIESEL	CELL 7 BAG CART 1	ENGINE OIL

BAROMETER 740.2 MM HG (29.14 IN HG)	CVS: 71.0°F RH 69.0 PCT AH 80.2 GR/LB	ENGINE DEW PT. 14.9°C (58.9°F)
ENGINE AIR TEMP. 24.4°C (76.0°F)	ENGINE ABS. HUM. 10.9 G/KG (76.6 GR/LB)	NOX HUMIDITY C.F. 1.004
		DRY-TO-WET C.F. .977

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1207.3
TOT. BLOWER RATE SCMM (SCFM)	63.05 (2226.5)
TOT. 90MM RATE SCMM (SCFM)	.06 (2.03)
TOT. 20X20 RATE SCMM (SCFM)	1.75 (61.9)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.09 (3.32)
TOTAL FLOW STD. CU. METRES(SCF)	1307.1 (46154.)
HC SAMPLE METER/RANGE/PPM	.2/ 76/ 20.14
HC BCKGRD METER/RANGE/PPM	.1/ 76/ 4.97
CO SAMPLE METER/RANGE/PPM	33.6/ 13/ 30.71
CO BCKGRD METER/RANGE/PPM	3.0/ 13/ 2.63
CO2 SAMPLE METER/RANGE/PCT	69.0/ 11/ .5764
CO2 BCKGRD METER/RANGE/PCT	8.1/ 11/ .0476
NOX SAMPLE METER/RANGE/PPM (D)	.5/ 73/ 40.07
NOX BCKGRD METER/RANGE/PPM	.2/ 2/ .21
DILUTION FACTOR	23.47
HC CONCENTRATION PPM	15.38
CO CONCENTRATION PPM	27.23
CO2 CONCENTRATION PCT	.5307
NOX CONCENTRATION PPM	38.94
HC MASS GRAMS	11.540
CO MASS GRAMS	41.441
CO2 MASS GRAMS	12691.30
NOX MASS GRAMS	97.722
FUEL KG (LB)	4.016 (8.85)
KW HR (HP HR)	16.45 (22.06)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.702(.523) (.52) (CONT)	90 MM FILTER NUMBERS	P90-17	P90-18
BSCO G/KW HR (G/HP HR)	2.519(1.879) (1.88)	90 MM FILTER WT. GAINS (MG)	3.104	.196
BSNOX G/KW HR (G/HP HR)	5.941(4.430) (4.43) (CONT)	PARTICULATE GRAMS/TEST	3.722	
PART. G/KW HR (G/HP HR)	.226(.169) (.17)			
BSFC KG/KW HR (LB/HP HR)	.244(.401)			
WORK KW HR (HP HR)	16.45(22.06)			
BSCO2 G/KW HR (G/HP HR)	772. (575.)			

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER PROTO	TEST C206104A RUN	DIESEL 2D EM-1816-F
ENGINE MODEL 91 DD SERIES 60	DATE 6/10/94 TIME 11:50	HCR 1.90 FID RES. FAC. 1.000
ENGINE 11.1 L(677. CID) I-6	COMPUTER PROGRAM HDT 3.1-R	H .138 C .862 O .000 X .000
ENGINE CYCLE DIESEL	CELL 7 BAG CART 1	ENGINE OIL

BAROMETER 741.4 MM HG (29.19 IN HG)	CVS: 71.0°F RH 73.0 PCT AH 85.0 GR/LB	ENGINE DEW PT. 14.5°C (58.1°F)
ENGINE AIR TEMP. 25.6°C (78.0°F)	ENGINE ABS. HUM. 10.6 G/KG (74.2 GR/LB)	NOX HUMIDITY C.F. .998
		DRY-TO-WET C.F. .976

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1206.9
TOT. BLOWER RATE SCMM (SCFM)	63.15 (2229.8)
TOT. 90MM RATE SCMM (SCFM)	.06 (2.05)
TOT. 20X20 RATE SCMM (SCFM)	1.72 (60.6)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.09 (3.32)
TOTAL FLOW STD. CU. METRES(SCF)	1307.8 (46180.)
HC SAMPLE METER/RANGE/PPM	.2/ 76/ 20.86
HC BCKGRD METER/RANGE/PPM	.1/ 76/ 5.25
CO SAMPLE METER/RANGE/PPM	26.1/ 13/ 23.60
CO BCKGRD METER/RANGE/PPM	.4/ 13/ .35
CO2 SAMPLE METER/RANGE/PCT	65.8/ 11/ .5401
CO2 BCKGRD METER/RANGE/PCT	7.7/ 11/ .0452
NOX SAMPLE METER/RANGE/PPM (D)	.5/ 73/ 39.34
NOX BCKGRD METER/RANGE/PPM	.4/ 2/ .42
DILUTION FACTOR	24.50
HC CONCENTRATION PPM	15.82
CO CONCENTRATION PPM	22.47
CO2 CONCENTRATION PCT	.4968
NOX CONCENTRATION PPM	37.98
HC MASS GRAMS	11.979
CO MASS GRAMS	34.211
CO2 MASS GRAMS	11885.77
NOX MASS GRAMS	94.802
FUEL KG (LB)	3.792 (8.36)
KW HR (HP HR)	16.23 (21.76)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.738(.551) (.55) (CONT)	90 MM FILTER NUMBERS	P90-19	P90-20
BSCO G/KW HR (G/HP HR)	2.108(1.572) (1.57)	90 MM FILTER WT. GAINS (MG)	3.271	.147
BSNOX G/KW HR (G/HP HR)	5.842(4.357) (4.36) (CONT)	PARTICULATE GRAMS/TEST	3.826	
PART. G/KW HR (G/HP HR)	.236(.176) (.18)			
BSFC KG/KW HR (LB/HP HR)	.234(.384)			
WORK KW HR (HP HR)	16.23(21.76)			
BSCO2 G/KW HR (G/HP HR)	732. (546.)			

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
EPA HOT-TRANS ENGINE EMISSION RESULTS

PROJECT NO. 02-5137-506

ENGINE NUMBER PROTO	TEST C206104B RUN	DIESEL 2D EM-1816-F
ENGINE MODEL 91 DD SERIES 60	DATE 6/10/94 TIME 12:30	HCR 1.90 FID RES. FAC. 1.000
ENGINE 11.1 L(677. CID) I-6	COMPUTER PROGRAM HDT 3.1-R	H .138 C .862 O .000 X .000
ENGINE CYCLE DIESEL	CELL 7 BAG CART 1	ENGINE OIL

BAROMETER 741.2 MM HG (29.18 IN HG)	CVS: 73.0°F RH 65.0 PCT AH 81.7 GR/LB	ENGINE DEW PT. 14.8°C (58.7°F)
ENGINE AIR TEMP. 25.6°C (78.0°F)	ENGINE ABS. HUM. 10.8 G/KG (75.9 GR/LB)	NOX HUMIDITY C.F. 1.002
		DRY-TO-WET C.F. .976

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1206.9
TOT. BLOWER RATE SCMM (SCFM)	63.19 (2231.4)
TOT. 90MM RATE SCMM (SCFM)	.06 (2.04)
TOT. 20X20 RATE SCMM (SCFM)	1.77 (62.6)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.09 (3.32)
TOTAL FLOW STD. CU. METRES(SCF)	1309.9 (46252.)
HC SAMPLE METER/RANGE/PPM	.2/ 76/ 20.83
HC BCKGRD METER/RANGE/PPM	.1/ 76/ 5.08
CO SAMPLE METER/RANGE/PPM	25.9/ 13/ 23.41
CO BCKGRD METER/RANGE/PPM	.1/ 13/ .09
CO2 SAMPLE METER/RANGE/PCT	65.8/ 11/ .5401
CO2 BCKGRD METER/RANGE/PCT	7.6/ 11/ .0446
NOX SAMPLE METER/RANGE/PPM (D)	.5/ 73/ 39.16
NOX BCKGRD METER/RANGE/PPM	.3/ 2/ .31
DILUTION FACTOR	24.50
HC CONCENTRATION PPM	15.96
CO CONCENTRATION PPM	22.59
CO2 CONCENTRATION PCT	.4974
NOX CONCENTRATION PPM	37.93
HC MASS GRAMS	12.099
CO MASS GRAMS	34.449
CO2 MASS GRAMS	11918.60
NOX MASS GRAMS	95.248
FUEL KG (LB)	3.802 (8.38)
KW HR (HP HR)	16.26 (21.80)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.744(.555) (.55) (CONT)
BSCO G/KW HR (G/HP HR)	2.119(1.580) (1.58)
BSNOX G/KW HR (G/HP HR)	5.859(4.369) (4.37) (CONT)
PART. G/KW HR (G/HP HR)	.237(.177) (.18)
BSFC KG/KW HR (LB/HP HR)	.234(.385)
WORK KW HR (HP HR)	16.26(21.80)
BSCO2 G/KW HR (G/HP HR)	733. (547.)

90 MM FILTER NUMBERS	P90-21	P90-22
90 MM FILTER WT. GAINS (MG)	3.262	.148
PARTICULATE GRAMS/TEST	3.851	

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA HOT-TRANS ENGINE EMISSION RESULTS

PROJECT NO. 02-5137-506

ENGINE NUMBER PROTO	TEST R06104B RUN	DIESEL 2D EM-1749-F
ENGINE MODEL 91 DD SERIES 60	DATE 6/10/94 TIME 3:10	HCR 1.79 FID RES. FAC. 1.000
ENGINE 11.1 L(677. CID) I-6	COMPUTER PROGRAM HDT 3.1-R	H .130 C .870 O .000 X .000
ENGINE CYCLE DIESEL	CELL 7 BAG CART 1	ENGINE OIL

BAROMETER 739.6 MM HG (29.12 IN HG)	CVS: 73.0°F RH 61.0 PCT AH 76.9 GR/LB	ENGINE DEW PT. 14.8°C (58.6°F)
ENGINE AIR TEMP. 25.6°C (78.0°F)	ENGINE ABS. HUM. 10.8 G/KG (75.8 GR/LB)	NOX HUMIDITY C.F. 1.002
		DRY-TO-WET C.F. .977

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1206.3
TOT. BLOWER RATE SCMM (SCFM)	62.92 (2221.7)
TOT. 90MM RATE SCMM (SCFM)	.06 (2.04)
TOT. 20X20 RATE SCMM (SCFM)	1.74 (61.6)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.09 (3.31)
TOTAL FLOW STD. CU. METRES(SCF)	1303.1 (46014.)
HC SAMPLE METER/RANGE/PPM	.2/ 76/ 20.65
HC BCKGRD METER/RANGE/PPM	.1/ 76/ 5.00
CO SAMPLE METER/RANGE/PPM	33.3/ 13/ 30.42
CO BCKGRD METER/RANGE/PPM	.6/ 13/ .52
CO2 SAMPLE METER/RANGE/PCT	69.3/ 11/ .5798
CO2 BCKGRD METER/RANGE/PCT	8.5/ 11/ .0501
NOX SAMPLE METER/RANGE/PPM (D)	.5/ 73/ 41.17
NOX BCKGRD METER/RANGE/PPM	.4/ 2/ .42
DILUTION FACTOR	23.33
HC CONCENTRATION PPM	15.86
CO CONCENTRATION PPM	28.99
CO2 CONCENTRATION PCT	.5318
NOX CONCENTRATION PPM	39.84
HC MASS GRAMS	11.866
CO MASS GRAMS	43.985
CO2 MASS GRAMS	12679.00
NOX MASS GRAMS	99.489
FUEL KG (LB)	4.014 (8.85)
KW HR (HP HR)	16.68 (22.37)

TOTAL RESULTS

BSHC	G/KW HR (G/HP HR)	.711(.530) (.53) (CONT)
BSCO	G/KW HR (G/HP HR)	2.637(1.966) (1.97)
BSNOX	G/KW HR (G/HP HR)	5.964(4.447) (4.45) (CONT)
PART.	G/KW HR (G/HP HR)	.224(.167) (.17)
BSFC	KG/KW HR (LB/HP HR)	.241(.396)
WORK	KW HR (HP HR)	16.68(22.37)
BSCO2	G/KW HR (G/HP HR)	760. (567.)

90 MM FILTER NUMBERS	P90-23	P90-24
90 MM FILTER WT. GAINS (MG)	3.130	.204
PARTICULATE GRAMS/TEST	3.743	

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA HOT-TRANS ENGINE EMISSION RESULTS   PROJECT NO. 02-5137-506

ENGINE NUMBER PROTO	TEST C306134A RUN	DIESEL 2D EM-1818-F
ENGINE MODEL 91 DD SERIES 60	DATE 6/13/94 TIME 1:10	HCR 1.90 FID RES. FAC. 1.000
ENGINE 11.1 L(677. CID) I-6	COMPUTER PROGRAM HDT 3.2-R	H .138 C .862 O .000 X .000
ENGINE CYCLE DIESEL	CELL 7 BAG CART 1	ENGINE OIL

BAROMETER 741.4 MM HG (29.19 IN HG)	CVS: 74.0°F RH 62.0 PCT AH 79.9 GR/LB	ENGINE DEW PT. 14.9°C (58.9°F)
ENGINE AIR TEMP. 25.6°C (78.0°F)	ENGINE ABS. HUM. 10.9 G/KG (76.4 GR/LB)	NOX HUMIDITY C.F. 1.004
		DRY-TO-WET C.F. .977

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1207.0
TOT. BLOWER RATE SCMM (SCFM)	62.86 (2219.6)
TOT. 90MM RATE SCMM (SCFM)	.06 (2.01)
TOT. 20X20 RATE SCMM (SCFM)	1.66 (58.7)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.09 (3.33)
TOTAL FLOW STD. CU. METRES(SCF)	1301.0 (45939.)
HC SAMPLE METER/RANGE/PPM	.3/ 76/ 23.13
HC BCKGRD METER/RANGE/PPM	.1/ 76/ 5.81
CO SAMPLE METER/RANGE/PPM	27.6/ 13/ 25.01
CO BCKGRD METER/RANGE/PPM	.1/ 13/ .09
CO2 SAMPLE METER/RANGE/PCT	66.6/ 11/ .5491
CO2 BCKGRD METER/RANGE/PCT	7.7/ 11/ .0452
NOX SAMPLE METER/RANGE/PPM (D)	.5/ 73/ 39.85
NOX BCKGRD METER/RANGE/PPM	.4/ 2/ .42
DILUTION FACTOR	24.08
HC CONCENTRATION PPM	17.56
CO CONCENTRATION PPM	24.16
CO2 CONCENTRATION PCT	.5058
NOX CONCENTRATION PPM	38.52
HC MASS GRAMS	13.225
CO MASS GRAMS	36.593
CO2 MASS GRAMS	12037.90
NOX MASS GRAMS	96.199
FUEL KG (LB)	3.842 (8.47)
KW HR (HP HR)	16.11 (21.61)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.821(.612) (.61) (CONT)	90 MM FILTER NUMBERS	P90-27	P90-28
BSCO G/KW HR (G/HP HR)	2.271(1.693) (1.69)	90 MM FILTER WT. GAINS (MG)	2.903	.155
BSNOX G/KW HR (G/HP HR)	5.970(4.452) (4.45) (CONT)	PARTICULATE GRAMS/TEST	3.482	
PART. G/KW HR (G/HP HR)	.216(.161) (.16)			
BSFC KG/KW HR (LB/HP HR)	.238(.392)			
WORK KW HR (HP HR)	16.11(21.61)			
BSCO2 G/KW HR (G/HP HR)	747. (557.)			

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER PROTO	TEST C306134B RUN	DIESEL 2D EM-1818-F
ENGINE MODEL 91 DD SERIES 60	DATE 6/13/94 TIME 1:50	HCR 1.90 FID RES. FAC. 1.000
ENGINE 11.1 L(677. CID) I-6	COMPUTER PROGRAM HDT 3.2-R	H .138 C .862 O .000 X .000
ENGINE CYCLE DIESEL	CELL 7 BAG CART 1	ENGINE OIL

BAROMETER 740.9 MM HG (29.17 IN HG)	CVS: 75.0°F RH 59.0 PCT AH 78.3 GR/LB	ENGINE DEW PT. 14.8°C (58.7°F)
ENGINE AIR TEMP. 25.6°C (78.0°F)	ENGINE ABS. HUM. 10.8 G/KG (75.9 GR/LB)	NOX HUMIDITY C.F. 1.002
		DRY-TO-WET C.F. .977

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1207.0
TOT. BLOWER RATE SCMM (SCFM)	63.18 (2230.8)
TOT. 90MM RATE SCMM (SCFM)	.06 (2.01)
TOT. 20X20 RATE SCMM (SCFM)	1.71 (60.6)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.09 (3.31)
TOTAL FLOW STD. CU. METRES(SCF)	1308.4 (46201.)
HC SAMPLE METER/RANGE/PPM	.3/ 76/ 23.82
HC BCKGRD METER/RANGE/PPM	.1/ 76/ 5.52
CO SAMPLE METER/RANGE/PPM	28.3/ 13/ 25.67
CO BCKGRD METER/RANGE/PPM	.2/ 13/ .17
CO2 SAMPLE METER/RANGE/PCT	65.9/ 11/ .5412
CO2 BCKGRD METER/RANGE/PCT	7.5/ 11/ .0439
NOX SAMPLE METER/RANGE/PPM (D)	.5/ 73/ 39.04
NOX BCKGRD METER/RANGE/PPM	.4/ 2/ .42
DILUTION FACTOR	24.42
HC CONCENTRATION PPM	18.53
CO CONCENTRATION PPM	24.75
CO2 CONCENTRATION PCT	.4991
NOX CONCENTRATION PPM	37.75
HC MASS GRAMS	14.031
CO MASS GRAMS	37.698
CO2 MASS GRAMS	11946.39
NOX MASS GRAMS	94.679
FUEL KG (LB)	3.815 (8.41)
KW HR (HP HR)	16.27 (21.82)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.862(.643) (.64) (CONT)	90 MM FILTER NUMBERS	P90-29 P90-30
BSCO G/KW HR (G/HP HR)	2.317(1.728) (1.73)	90 MM FILTER WT. GAINS (MG)	2.651 .173
BSNOX G/KW HR (G/HP HR)	5.819(4.339) (4.34) (CONT)	PARTICULATE GRAMS/TEST	3.225
PART. G/KW HR (G/HP HR)	.198(.148) (.15)		
BSFC KG/KW HR (LB/HP HR)	.234(.385)		
WORK KW HR (HP HR)	16.27(21.82)		
BSCO2 G/KW HR (G/HP HR)	734. (547.)		

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER PROTO	TEST R06134B RUN	DIESEL 2D EM-1749-F
ENGINE MODEL 91 DD SERIES 60	DATE 6/13/94 TIME 4:15	HCR 1.79 FID RES. FAC. 1.000
ENGINE 11.1 L(677. CID) I-6	COMPUTER PROGRAM HDT 3.2-R	H .130 C .870 O .000 X .000
ENGINE CYCLE DIESEL	CELL 7 BAG CART 1	ENGINE OIL

BAROMETER 741.9 MM HG (29.21 IN HG)	CVS: 74.0°F RH 62.0 PCT AH 79.9 GR/LB	ENGINE DEW PT. 15.1°C (59.1°F)
ENGINE AIR TEMP. 25.6°C (78.0°F)	ENGINE ABS. HUM. 11.0 G/KG (76.9 GR/LB)	NOX HUMIDITY C.F. 1.005
		DRY-TO-WET C.F. .977

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1206.8
TOT. BLOWER RATE SCMM (SCFM)	63.25 (2233.4)
TOT. 90MM RATE SCMM (SCFM)	.06 (2.00)
TOT. 20X20 RATE SCMM (SCFM)	1.64 (57.8)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.09 (3.33)
TOTAL FLOW STD. CU. METRES(SCF)	1308.1 (46191.)
HC SAMPLE METER/RANGE/PPM	.3/ 76/ 22.28
HC BCKGRD METER/RANGE/PPM	.1/ 76/ 5.35
CO SAMPLE METER/RANGE/PPM	32.7/ 13/ 29.85
CO BCKGRD METER/RANGE/PPM	.2/ 13/ .17
CO2 SAMPLE METER/RANGE/PCT	68.4/ 11/ .5695
CO2 BCKGRD METER/RANGE/PCT	7.6/ 11/ .0446
NOX SAMPLE METER/RANGE/PPM (D)	.5/ 73/ 40.38
NOX BCKGRD METER/RANGE/PPM	.3/ 2/ .31
DILUTION FACTOR	23.74
HC CONCENTRATION PPM	17.16
CO CONCENTRATION PPM	28.77
CO2 CONCENTRATION PCT	.5268
NOX CONCENTRATION PPM	39.14
HC MASS GRAMS	12.881
CO MASS GRAMS	43.808
CO2 MASS GRAMS	12606.85
NOX MASS GRAMS	98.419
FUEL KG (LB)	3.992 (8.80)
KW HR (HP HR)	16.61 (22.27)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.776(.578) (.58) (CONT)
BSCO G/KW HR (G/HP HR)	2.638(1.967) (1.97)
BSNOX G/KW HR (G/HP HR)	5.926(4.419) (4.42) (CONT)
PART. G/KW HR (G/HP HR)	.237(.177) (.18)
BSFC KG/KW HR (LB/HP HR)	.240(.395)
WORK KW HR (HP HR)	16.61(22.27)
BSCO2 G/KW HR (G/HP HR)	759. (566.)

90 MM FILTER NUMBERS	P90-31	P90-32
90 MM FILTER WT. GAINS (MG)	3.209	.219
PARTICULATE GRAMS/TEST	3.933	

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER PROTO	TEST R06134C RUN	DIESEL 2D EM-1749-F
ENGINE MODEL 91 DD SERIES 60	DATE 6/13/94 TIME 4:55	HCR 1.79 FID RES. FAC. 1.000
ENGINE 11.1 L(677. CID) I-6	COMPUTER PROGRAM HDT 3.2-R	H .130 C .870 O .000 X .000
ENGINE CYCLE DIESEL	CELL 7 BAG CART 1	ENGINE OIL

BAROMETER 741.9 MM HG (29.21 IN HG)	CVS: 74.0°F RH 62.0 PCT AH 79.9 GR/LB	ENGINE DEW PT. 15.1°C (59.1°F)
ENGINE AIR TEMP. 25.0°C (77.0°F)	ENGINE ABS. HUM. 11.0 G/KG (76.9 GR/LB)	NOX HUMIDITY C.F. 1.005
		DRY-TO-WET C.F. .977

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1207.6
TOT. BLOWER RATE SCMM (SCFM)	63.23 (2232.6)
TOT. 90MM RATE SCMM (SCFM)	.06 (2.02)
TOT. 20X20 RATE SCMM (SCFM)	1.65 (58.3)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.09 (3.30)
TOTAL FLOW STD. CU. METRES(SCF)	1308.9 (46216.)
HC SAMPLE METER/RANGE/PPM	.3/ 76/ 22.89
HC BCKGRD METER/RANGE/PPM	.1/ 76/ 6.48
CO SAMPLE METER/RANGE/PPM	32.8/ 13/ 29.94
CO BCKGRD METER/RANGE/PPM	1.1/ 13/ .96
CO2 SAMPLE METER/RANGE/PCT	68.4/ 11/ .5695
CO2 BCKGRD METER/RANGE/PCT	8.1/ 11/ .0476
NOX SAMPLE METER/RANGE/PPM (D)	.5/ 73/ 40.11
NOX BCKGRD METER/RANGE/PPM	.4/ 2/ .42
DILUTION FACTOR	23.74
HC CONCENTRATION PPM	16.68
CO CONCENTRATION PPM	28.12
CO2 CONCENTRATION PCT	.5238
NOX CONCENTRATION PPM	38.78
HC MASS GRAMS	12.533
CO MASS GRAMS	42.847
CO2 MASS GRAMS	12543.06
NOX MASS GRAMS	97.560
FUEL KG (LB)	3.971 (8.75)
KW HR (HP HR)	16.64 (22.32)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.753(.562) (.56) (CONT)	90 MM FILTER NUMBERS	P90-33	P90-34
BSCO G/KW HR (G/HP HR)	2.574(1.920) (1.92)	90 MM FILTER WT. GAINS (MG)	3.163	.195
BSNOX G/KW HR (G/HP HR)	5.862(4.371) (4.37) (CONT)	PARTICULATE GRAMS/TEST	3.815	
PART. G/KW HR (G/HP HR)	.229(.171) (.17)			
BSFC KG/KW HR (LB/HP HR)	.239(.392)			
WORK KW HR (HP HR)	16.64(22.32)			
BSCO2 G/KW HR (G/HP HR)	754. (562.)			

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EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER PROTO	TEST R06154A RUN	DIESEL 2D EM-1749-F
ENGINE MODEL 91 DD SERIES 60	DATE 6/15/94 TIME 9:36	HCR 1.79 FID RES. FAC. 1.000
ENGINE 11.1 L(677. CID) I-6	COMPUTER PROGRAM HDT 3.2-R	H .130 C .870 O .000 X .000
ENGINE CYCLE DIESEL	CELL 7 BAG CART 1	ENGINE OIL

BAROMETER 741.9 MM HG (29.21 IN HG)	CVS: 75.0°F RH 66.0 PCT AH 88.5 GR/LB	ENGINE DEW PT. 15.4°C (59.8°F)
ENGINE AIR TEMP. 24.4°C (76.0°F)	ENGINE ABS. HUM. 11.3 G/KG (78.9 GR/LB)	NOX HUMIDITY C.F. 1.010
		DRY-TO-WET C.F. .975

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1207.3
TOT. BLOWER RATE SCMM (SCFM)	62.90 (2220.9)
TOT. 90MM RATE SCMM (SCFM)	.06 (2.00)
TOT. 20X20 RATE SCMM (SCFM)	1.73 (61.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.09 (3.31)
TOTAL FLOW STD. CU. METRES(SCF)	1303.4 (46022.)
HC SAMPLE METER/RANGE/PPM	.3/ 76/ 21.31
HC BCKGRD METER/RANGE/PPM	.1/ 76/ 5.88
CO SAMPLE METER/RANGE/PPM	31.7/ 13/ 28.89
CO BCKGRD METER/RANGE/PPM	.0/ 13/ .00
CO2 SAMPLE METER/RANGE/PCT	68.8/ 11/ .5741
CO2 BCKGRD METER/RANGE/PCT	8.5/ 11/ .0501
NOX SAMPLE METER/RANGE/PPM (D)	.5/ 73/ 40.47
NOX BCKGRD METER/RANGE/PPM	.8/ 2/ .83
DILUTION FACTOR	23.56
HC CONCENTRATION PPM	15.68
CO CONCENTRATION PPM	27.96
CO2 CONCENTRATION PCT	.5261
NOX CONCENTRATION PPM	38.66
HC MASS GRAMS	11.730
CO MASS GRAMS	42.428
CO2 MASS GRAMS	12543.54
NOX MASS GRAMS	97.342
FUEL KG (LB)	3.970 (8.75)
KW HR (HP HR)	16.72 (22.42)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.702(.523) (.52) (CONT)	90 MM FILTER NUMBERS	P90-35	P90-36
BSCO G/KW HR (G/HP HR)	2.538(1.892) (1.89)	90 MM FILTER WT. GAINS (MG)	3.180	.251
BSNOX G/KW HR (G/HP HR)	5.822(4.342) (4.34) (CONT)	PARTICULATE GRAMS/TEST	3.924	
PART. G/KW HR (G/HP HR)	.235(.175) (.18)			
BSFC KG/KW HR (LB/HP HR)	.237(.390)			
WORK KW HR (HP HR)	16.72(22.42)			
BSCO2 G/KW HR (G/HP HR)	750. (559.)			

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EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER PROTO	TEST C306154A RUN	DIESEL 2D EM-1818-F
ENGINE MODEL 91 DD SERIES 60	DATE 6/15/94 TIME 1:00	HCR 1.90 FID RES. FAC. 1.000
ENGINE 11.1 L(677. CID) I-6	COMPUTER PROGRAM HDT 3.2-R	H .138 C .862 O .000 X .000
ENGINE CYCLE DIESEL	CELL 7 BAG CART 1	ENGINE OIL

BAROMETER 741.9 MM HG (29.21 IN HG)	CVS: 74.0°F RH 70.0 PCT AH 90.2 GR/LB	ENGINE DEW PT. 15.2°C (59.4°F)
ENGINE AIR TEMP. 25.0°C (77.0°F)	ENGINE ABS. HUM. 11.1 G/KG (77.8 GR/LB)	NOX HUMIDITY C.F. 1.007
		DRY-TO-WET C.F. .974

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1207.4
TOT. BLOWER RATE SCMM (SCFM)	63.00 (2224.6)
TOT. 90MM RATE SCMM (SCFM)	.06 (1.99)
TOT. 20X20 RATE SCMM (SCFM)	1.67 (59.1)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.09 (3.33)
TOTAL FLOW STD. CU. METRES(SCF)	1304.5 (46062.)
HC SAMPLE METER/RANGE/PPM	.3/ 76/ 23.66
HC BCKGRD METER/RANGE/PPM	.1/ 76/ 5.45
CO SAMPLE METER/RANGE/PPM	27.4/ 13/ 24.82
CO BCKGRD METER/RANGE/PPM	.2/ 13/ .17
CO2 SAMPLE METER/RANGE/PCT	66.4/ 11/ .5468
CO2 BCKGRD METER/RANGE/PCT	7.8/ 11/ .0458
NOX SAMPLE METER/RANGE/PPM (D)	.5/ 73/ 39.93
NOX BCKGRD METER/RANGE/PPM	1.0/ 2/ 1.04
DILUTION FACTOR	24.18
HC CONCENTRATION PPM	18.44
CO CONCENTRATION PPM	23.83
CO2 CONCENTRATION PCT	.5029
NOX CONCENTRATION PPM	37.91
HC MASS GRAMS	13.920
CO MASS GRAMS	36.195
CO2 MASS GRAMS	12002.04
NOX MASS GRAMS	95.264
FUEL KG (LB)	3.831 (8.45)
KW HR (HP HR)	16.43 (22.03)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.847(.632) (.63) (CONT)
BSCO G/KW HR (G/HP HR)	2.203(1.643) (1.64)
BSNOX G/KW HR (G/HP HR)	5.799(4.324) (4.32) (CONT)
PART. G/KW HR (G/HP HR)	.206(.154) (.15)
BSFC KG/KW HR (LB/HP HR)	.233(.383)
WORK KW HR (HP HR)	16.43(22.03)
BSCO2 G/KW HR (G/HP HR)	731. (545.)

90 MM FILTER NUMBERS	P90-37	P90-38
90 MM FILTER WT. GAINS (MG)	2.725	.228
PARTICULATE GRAMS/TEST	3.389	

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER PROTO	TEST C306154B RUN	DIESEL 2D EM-1818-F
ENGINE MODEL 91 DD SERIES 60	DATE 6/15/94 TIME 1:40	HCR 1.90 FID RES. FAC. 1.000
ENGINE 11.1 L(677. CID) I-6	COMPUTER PROGRAM HDT 3.2-R	H .138 C .862 O .000 X .000
ENGINE CYCLE DIESEL	CELL 7 BAG CART 1	ENGINE OIL

BAROMETER 741.9 MM HG (29.21 IN HG)	CVS: 75.0°F RH 70.0 PCT AH 93.8 GR/LB	ENGINE DEW PT. 14.8°C (58.6°F)
ENGINE AIR TEMP. 25.0°C (77.0°F)	ENGINE ABS. HUM. 10.8 G/KG (75.5 GR/LB)	NOX HUMIDITY C.F. 1.001
		DRY-TO-WET C.F. .973

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1206.9
TOT. BLOWER RATE SCMM (SCFM)	63.06 (2226.6)
TOT. 90MM RATE SCMM (SCFM)	.06 (1.99)
TOT. 20X20 RATE SCMM (SCFM)	1.78 (62.7)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.09 (3.31)
TOTAL FLOW STD. CU. METRES(SCF)	1307.1 (46155.)
HC SAMPLE METER/RANGE/PPM	.3/ 76/ 23.74
HC BCKGRD METER/RANGE/PPM	.1/ 76/ 5.68
CO SAMPLE METER/RANGE/PPM	28.5/ 13/ 25.86
CO BCKGRD METER/RANGE/PPM	.3/ 13/ .26
CO2 SAMPLE METER/RANGE/PCT	67.0/ 11/ .5536
CO2 BCKGRD METER/RANGE/PCT	8.2/ 11/ .0483
NOX SAMPLE METER/RANGE/PPM (D)	.5/ 73/ 39.96
NOX BCKGRD METER/RANGE/PPM	.9/ 2/ .93
DILUTION FACTOR	23.88
HC CONCENTRATION PPM	18.30
CO CONCENTRATION PPM	24.75
CO2 CONCENTRATION PCT	.5073
NOX CONCENTRATION PPM	38.01
HC MASS GRAMS	13.844
CO MASS GRAMS	37.660
CO2 MASS GRAMS	12131.80
NOX MASS GRAMS	95.138
FUEL KG (LB)	3.873 (8.54)
KW HR (HP HR)	16.32 (21.89)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.848(.632) (.63) (CONT)	90 MM FILTER NUMBERS	P90-39	P90-40
BSCO G/KW HR (G/HP HR)	2.307(1.720) (1.72)	90 MM FILTER WT. GAINS (MG)	2.649	.198
BSNOX G/KW HR (G/HP HR)	5.828(4.346) (4.35) (CONT)	PARTICULATE GRAMS/TEST	3.283	
PART. G/KW HR (G/HP HR)	.201(.150) (.15)			
BSFC KG/KW HR (LB/HP HR)	.237(.390)			
WORK KW HR (HP HR)	16.32(21.89)			
BSCO2 G/KW HR (G/HP HR)	743. (554.)			

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER PROTO	TEST R06154B RUN	DIESEL 2D EM-1749-F
ENGINE MODEL 91 DD SERIES 60	DATE 6/15/94 TIME 4:00	HCR 1.79 FID RES. FAC. 1.000
ENGINE 11.1 L(677. CID) I-6	COMPUTER PROGRAM HDT 3.2-R	H .130 C .870 O .000 X .000
ENGINE CYCLE DIESEL	CELL 7 BAG CART 1	ENGINE OIL

BAROMETER 740.9 MM HG (29.17 IN HG)	CVS: 77.0°F RH 71.0 PCT AH 101.7 GR/LB	ENGINE DEW PT. 14.9°C (58.8°F)
ENGINE AIR TEMP. 24.4°C (76.0°F)	ENGINE ABS. HUM. 10.9 G/KG (76.2 GR/LB)	NOX HUMIDITY C.F. 1.003
		DRY-TO-WET C.F. .972

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1207.2
TOT. BLOWER RATE SCMM (SCFM)	62.80 (2217.6)
TOT. 90MM RATE SCMM (SCFM)	.06 (1.98)
TOT. 20X20 RATE SCMM (SCFM)	1.88 (66.3)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.09 (3.28)
TOTAL FLOW STD. CU. METRES(SCF)	1304.4 (46058.)
HC SAMPLE METER/RANGE/PPM	.3/ 76/ 22.48
HC BCKGRD METER/RANGE/PPM	.1/ 76/ 6.04
CO SAMPLE METER/RANGE/PPM	32.0/ 13/ 29.18
CO BCKGRD METER/RANGE/PPM	.0/ 13/ .00
CO2 SAMPLE METER/RANGE/PCT	68.4/ 11/ .5695
CO2 BCKGRD METER/RANGE/PCT	7.4/ 11/ .0433
NOX SAMPLE METER/RANGE/PPM (D)	.5/ 73/ 40.61
NOX BCKGRD METER/RANGE/PPM	.1/ 2/ .10
DILUTION FACTOR	23.74
HC CONCENTRATION PPM	16.69
CO CONCENTRATION PPM	28.20
CO2 CONCENTRATION PCT	.5280
NOX CONCENTRATION PPM	39.37
HC MASS GRAMS	12.499
CO MASS GRAMS	42.819
CO2 MASS GRAMS	12598.69
NOX MASS GRAMS	98.514
FUEL KG (LB)	3.988 (8.79)
KW HR (HP HR)	16.75 (22.46)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.746(.556) (.56) (CONT)	90 MM FILTER NUMBERS	P90-41	P90-42
BSCO G/KW HR (G/HP HR)	2.557(1.906) (1.91)	90 MM FILTER WT. GAINS (MG)	3.107	.225
BSNOX G/KW HR (G/HP HR)	5.882(4.386) (4.39) (CONT)	PARTICULATE GRAMS/TEST	3.853	
PART. G/KW HR (G/HP HR)	.230(.172) (.17)			
BSFC KG/KW HR (LB/HP HR)	.238(.391)			
WORK KW HR (HP HR)	16.75(22.46)			
BSCO2 G/KW HR (G/HP HR)	752. (561.)			

APPENDIX D

REFERENCE AND CANDIDATE FUELS HOT-START TRANSIENT EMISSIONS ON 1990 GM 6.2L HEAVY-DUTY DIESEL ENGINE

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA HOT-TRANS ENGINE EMISSION RESULTS   PROJECT NO. 02-5137-506

ENGINE NUMBER	TEST R0923A8 RUN	DIESEL 2D EM-1749-F
ENGINE MODEL 0 ARMY GM 6.L	DATE 9/23/94 TIME 9:45	HCR 1.79 FID RES. FAC. 1.000
ENGINE 6.2 L(378. CID) V-8	COMPUTER PROGRAM HDT 3.2-R	H .130 C .870 O .000 X .000
ENGINE CYCLE DIESEL	CELL 8 BAG CART 1	ENGINE OIL
ENGINE SERIAL H126642		

BAROMETER 742.7 MM HG (29.24 IN HG)	CVS: 72.0°F RH 39.0 PCT AH 46.2 GR/LB	ENGINE DEW PT. 13.7°C (56.6°F)
ENGINE AIR TEMP. 25.0°C (77.0°F)	ENGINE ABS. HUM. 10.0 G/KG (70.1 GR/LB)	NOX HUMIDITY C.F. .988
		DRY-TO-WET C.F. .983

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1208.2
TOT. BLOWER RATE SCMM (SCFM)	33.79 (1193.3)
TOT. 90MM RATE SCMM (SCFM)	.04 (1.30)
TOT. 20X20 RATE SCMM (SCFM)	1.29 (45.7)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.10 (3.43)
TOTAL FLOW STD. CU. METRES(SCF)	709.2 (25043.)
HC SAMPLE METER/RANGE/PPM	3.6/ 84/ 17.75
HC BCKGRD METER/RANGE/PPM	5.2/ 82/ 5.20
CO SAMPLE METER/RANGE/PPM	26.5/ 13/ 23.83
CO BCKGRD METER/RANGE/PPM	.1/ 13/ .09
CO2 SAMPLE METER/RANGE/PCT	77.6/ 11/ .6796
CO2 BCKGRD METER/RANGE/PCT	8.4/ 11/ .0495
NOX SAMPLE METER/RANGE/PPM (D)	.3/ 83/ 24.12
NOX BCKGRD METER/RANGE/PPM	.2/ 2/ .21
DILUTION FACTOR	19.95
HC CONCENTRATION PPM	12.82
CO CONCENTRATION PPM	23.14
CO2 CONCENTRATION PCT	.6326
NOX CONCENTRATION PPM	23.52
HC MASS GRAMS	5.217
CO MASS GRAMS	19.108
CO2 MASS GRAMS	8207.53
NOX MASS GRAMS	31.505
FUEL KG (LB)	2.591 (5.71)
KW HR (HP HR)	7.37 (9.89)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.707(.527) (.53) (CONT)	90 MM FILTER NUMBERS	P90-45	P90-46
BSCO G/KW HR (G/HP HR)	2.591(1.932) (1.93)	90 MM FILTER WT. GAINS (MG)	2.804	.197
BSNOX G/KW HR (G/HP HR)	4.272(3.186) (3.19) (CONT)	PARTICULATE GRAMS/TEST	2.871	
PART. G/KW HR (G/HP HR)	.389(.290) (.29)			
BSFC KG/KW HR (LB/HP HR)	.351(.578)			
WORK KW HR (HP HR)	7.37(9.89)			
BSCO2 G/KW HR (G/HP HR)	1113. (830.)			

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER
ENGINE MODEL 0 ARMY GM 6.L
ENGINE 6.2 L(378. CID) V-8
ENGINE CYCLE DIESEL
ENGINE SERIAL H126642

TEST C10923A8 RUN
DATE 9/23/94 TIME 14:40
COMPUTER PROGRAM HDT 3.2-R
CELL 8 BAG CART 1

DIESEL 2D EM-1809-F
HCR 1.91 FID RES. FAC. 1.000
H .138 C .862 O .000 X .000
ENGINE OIL

BAROMETER 739.4 MM HG (29.11 IN HG)
ENGINE AIR TEMP. 24.4°C (76.0°F)

CVS: 71.0°F RH 34.0 PCT AH 39.9 GR/LB
ENGINE ABS. HUM. 10.3 G/KG (72.0 GR/LB)

ENGINE DEW PT. 14.0°C (57.2°F)
NOX HUMIDITY C.F. .992
DRY-TO-WET C.F. .985

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1208.2
TOT. BLOWER RATE SCMM (SCFM)	33.75 (1191.8)
TOT. 90MM RATE SCMM (SCFM)	.04 (1.25)
TOT. 20X20 RATE SCMM (SCFM)	1.26 (44.5)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.10 (3.45)
TOTAL FLOW STD. CU. METRES(SCF)	707.7 (24990.)
HC SAMPLE METER/RANGE/PPM	4.4/ 84/ 21.87
HC BCKGRD METER/RANGE/PPM	5.4/ 82/ 5.40
CO SAMPLE METER/RANGE/PPM	29.6/ 13/ 26.66
CO BCKGRD METER/RANGE/PPM	.2/ 13/ .19
CO2 SAMPLE METER/RANGE/PCT	76.6/ 11/ .6671
CO2 BCKGRD METER/RANGE/PCT	7.6/ 11/ .0446
NOX SAMPLE METER/RANGE/PPM (D)	.3/ 83/ 23.44
NOX BCKGRD METER/RANGE/PPM	.1/ 2/ .10
DILUTION FACTOR	19.83
HC CONCENTRATION PPM	16.74
CO CONCENTRATION PPM	25.84
CO2 CONCENTRATION PCT	.6248
NOX CONCENTRATION PPM	22.98
HC MASS GRAMS	6.860
CO MASS GRAMS	21.288
CO2 MASS GRAMS	8089.66
NOX MASS GRAMS	30.861
FUEL KG (LB)	2.579 (5.69)
KW HR (HP HR)	7.24 (9.71)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.947(.706) (.71) (CONT)
BSCO G/KW HR (G/HP HR)	2.940(2.192) (2.19)
BSNOX G/KW HR (G/HP HR)	4.262(3.178) (3.18) (CONT)
PART. G/KW HR (G/HP HR)	.305(.227) (.23)
BSFC KG/KW HR (LB/HP HR)	.356(.586)
WORK KW HR (HP HR)	7.24(9.71)
BSCO2 G/KW HR (G/HP HR)	1117. (833.)

90 MM FILTER NUMBERS	P90-47	P90-48
90 MM FILTER WT. GAINS (MG)	2.040	.184
PARTICULATE GRAMS/TEST	2.207	

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER	TEST C10923B8 RUN	DIESEL 2D EM-1809-F
ENGINE MODEL 0 ARMY GM 6.L	DATE 9/23/94 TIME 15:20	HCR 1.91 FID RES. FAC. 1.000
ENGINE 6.2 L(378. CID) V-8	COMPUTER PROGRAM HDT 3.2-R	H .138 C .862 O .000 X .000
ENGINE CYCLE DIESEL	CELL 8 BAG CART 1	ENGINE OIL
ENGINE SERIAL H126642		

BAROMETER 739.1 MM HG (29.10 IN HG)	CVS: 72.0°F RH 32.0 PCT AH 38.2 GR/LB	ENGINE DEW PT. 13.8°C (56.9°F)
ENGINE AIR TEMP. 25.0°C (77.0°F)	ENGINE ABS. HUM. 10.2 G/KG (71.3 GR/LB)	NOX HUMIDITY C.F. .990
		DRY-TO-WET C.F. .985

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1208.1
TOT. BLOWER RATE SCMM (SCFM)	33.63 (1187.4)
TOT. 90MM RATE SCMM (SCFM)	.04 (1.25)
TOT. 20X20 RATE SCMM (SCFM)	1.26 (44.5)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.10 (3.38)
TOTAL FLOW STD. CU. METRES(SCF)	705.1 (24897.)
HC SAMPLE METER/RANGE/PPM	4.3/ 84/ 21.33
HC BCKGRD METER/RANGE/PPM	5.5/ 82/ 5.50
CO SAMPLE METER/RANGE/PPM	28.8/ 13/ 25.93
CO BCKGRD METER/RANGE/PPM	.0/ 13/ .00
CO2 SAMPLE METER/RANGE/PCT	77.6/ 11/ .6796
CO2 BCKGRD METER/RANGE/PCT	.0/ 11/ .0000
NOX SAMPLE METER/RANGE/PPM (D)	.3/ 83/ 23.52
NOX BCKGRD METER/RANGE/PPM	.0/ 2/ .00
DILUTION FACTOR	19.47
HC CONCENTRATION PPM	16.11
CO CONCENTRATION PPM	25.31
CO2 CONCENTRATION PCT	.6796
NOX CONCENTRATION PPM	23.16
HC MASS GRAMS	6.580
CO MASS GRAMS	20.780
CO2 MASS GRAMS	8766.31
NOX MASS GRAMS	30.931
FUEL KG (LB)	2.793 (6.16)
KW HR (HP HR)	7.26 (9.73)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.907(.676) (.68) (CONT)
BSCO G/KW HR (G/HP HR)	2.864(2.136) (2.14)
BSNOX G/KW HR (G/HP HR)	4.263(3.179) (3.18) (CONT)
PART. G/KW HR (G/HP HR)	.305(.228) (.23)
BSFC KG/KW HR (LB/HP HR)	.385(.633)
WORK KW HR (HP HR)	7.26(9.73)
BSCO2 G/KW HR (G/HP HR)	1208. (901.)

90 MM FILTER NUMBERS	P90-49	P90-50
90 MM FILTER WT. GAINS (MG)	2.075	.174
PARTICULATE GRAMS/TEST	2.216	

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER	TEST R0923B8 RUN	DIESEL 2D EM-1749-F
ENGINE MODEL 0 ARMY GM 6.L	DATE 9/23/94 TIME 19:20	HCR 1.78 FID RES. FAC. 1.000
ENGINE 6.2 L(378. CID) V-8	COMPUTER PROGRAM HDT 3.2-R	H .130 C .870 O .000 X .000
ENGINE CYCLE DIESEL	CELL 8 BAG CART 1	ENGINE OIL
ENGINE SERIAL H126642		

BAROMETER 737.6 MM HG (29.04 IN HG)	CVS: 72.0°F RH 35.0 PCT AH 42.5 GR/LB	ENGINE DEW PT. 13.8°C (56.9°F)
ENGINE AIR TEMP. 24.4°C (76.0°F)	ENGINE ABS. HUM. 10.2 G/KG (71.4 GR/LB)	NOX HUMIDITY C.F. .991
		DRY-TO-WET C.F. .984

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1206.9
TOT. BLOWER RATE SCMM (SCFM)	33.55 (1184.8)
TOT. 90MM RATE SCMM (SCFM)	.03 (1.23)
TOT. 20X20 RATE SCMM (SCFM)	1.27 (45.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.10 (3.42)
TOTAL FLOW STD. CU. METRES(SCF)	703.2 (24830.)
HC SAMPLE METER/RANGE/PPM	3.8/ 84/ 19.15
HC BCKGRD METER/RANGE/PPM	7.2/ 82/ 7.20
CO SAMPLE METER/RANGE/PPM	26.1/ 13/ 23.47
CO BCKGRD METER/RANGE/PPM	.0/ 13/ .00
CO2 SAMPLE METER/RANGE/PCT	77.6/ 11/ .6796
CO2 BCKGRD METER/RANGE/PCT	7.3/ 11/ .0427
NOX SAMPLE METER/RANGE/PPM (D)	.3/ 83/ 24.21
NOX BCKGRD METER/RANGE/PPM	.2/ 2/ .21
DILUTION FACTOR	19.97
HC CONCENTRATION PPM	12.31
CO CONCENTRATION PPM	22.90
CO2 CONCENTRATION PCT	.6390
NOX CONCENTRATION PPM	23.63
HC MASS GRAMS	4.966
CO MASS GRAMS	18.749
CO2 MASS GRAMS	8220.65
NOX MASS GRAMS	31.485
FUEL KG (LB)	2.594 (5.72)
KW HR (HP HR)	7.30 (9.79)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.680(.507) (.51) (CONT)
BSCO G/KW HR (G/HP HR)	2.568(1.915) (1.92)
BSNOX G/KW HR (G/HP HR)	4.313(3.216) (3.22) (CONT)
PART. G/KW HR (G/HP HR)	.405(.302) (.30)
BSFC KG/KW HR (LB/HP HR)	.355(.584)
WORK KW HR (HP HR)	7.30(9.79)
BSCO2 G/KW HR (G/HP HR)	1126. (840.)

90 MM FILTER NUMBERS	P90-51	P90-52
90 MM FILTER WT. GAINS (MG)	2.764	.192
PARTICULATE GRAMS/TEST	2.958	

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER	TEST R0926A8 RUN	DIESEL 2D EM-1749-F
ENGINE MODEL 0 ARMY GM 6.L	DATE 9/26/94 TIME 10:20	HCR 1.78 FID RES. FAC. 1.000
ENGINE 6.2 L(378. CID) V-8	COMPUTER PROGRAM HDT 3.2-R	H .130 C .870 O .000 X .000
ENGINE CYCLE DIESEL	CELL 8 BAG CART 1	ENGINE OIL
ENGINE SERIAL H126642		

BAROMETER 742.2 MM HG (29.22 IN HG)	CVS: 73.0°F RH 46.0 PCT AH 57.7 GR/LB	ENGINE DEW PT. 14.1°C (57.4°F)
ENGINE AIR TEMP. 25.6°C (78.0°F)	ENGINE ABS. HUM. 10.3 G/KG (72.3 GR/LB)	NOX HUMIDITY C.F. .993
		DRY-TO-WET C.F. .981

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1208.1
TOT. BLOWER RATE SCMM (SCFM)	33.89 (1196.5)
TOT. 90MM RATE SCMM (SCFM)	.04 (1.28)
TOT. 20X20 RATE SCMM (SCFM)	1.26 (44.4)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.07 (2.59)
TOTAL FLOW STD. CU. METRES(SCF)	709.8 (25063.)
HC SAMPLE METER/RANGE/PPM	3.8/ 84/ 18.77
HC BCKGRD METER/RANGE/PPM	7.8/ 82/ 7.80
CO SAMPLE METER/RANGE/PPM	26.9/ 13/ 24.20
CO BCKGRD METER/RANGE/PPM	1.3/ 13/ 1.22
CO2 SAMPLE METER/RANGE/PCT	78.6/ 11/ .6922
CO2 BCKGRD METER/RANGE/PCT	8.8/ 11/ .0520
NOX SAMPLE METER/RANGE/PPM (D)	.3/ 83/ 24.93
NOX BCKGRD METER/RANGE/PPM	.3/ 2/ .31
DILUTION FACTOR	19.61
HC CONCENTRATION PPM	11.37
CO CONCENTRATION PPM	22.38
CO2 CONCENTRATION PCT	.6429
NOX CONCENTRATION PPM	24.15
HC MASS GRAMS	4.630
CO MASS GRAMS	18.493
CO2 MASS GRAMS	8347.62
NOX MASS GRAMS	32.555
FUEL KG (LB)	2.633 (5.81)
KW HR (HP HR)	7.33 (9.83)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.632(.471) (.47) (CONT)	90 MM FILTER NUMBERS	P90-55 P90-56
BSCO G/KW HR (G/HP HR)	2.523(1.881) (1.88)	90 MM FILTER WT. GAINS (MG)	2.970 .186
BSNOX G/KW HR (G/HP HR)	4.441(3.312) (3.31) (CONT)	PARTICULATE GRAMS/TEST	3.058
PART. G/KW HR (G/HP HR)	.417(.311) (.31)		
BSFC KG/KW HR (LB/HP HR)	.359(.591)		
WORK KW HR (HP HR)	7.33(9.83)		
BSCO2 G/KW HR (G/HP HR)	1139. (849.)		

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ENGINE NUMBER	TEST C10926A8 RUN	DIESEL 2D EM-1809-F
ENGINE MODEL 0 ARMY GM 6.L	DATE 9/26/94 TIME 14:30	HCR 1.91 FID RES. FAC. 1.000
ENGINE 6.2 L(378. CID) V-8	COMPUTER PROGRAM HDT 3.2-R	H .138 C .862 O .000 X .000
ENGINE CYCLE DIESEL	CELL 8 BAG CART 1	ENGINE OIL
ENGINE SERIAL H126642		

BAROMETER 739.6 MM HG (29.12 IN HG)	CVS: 75.0°F RH 48.0 PCT AH 63.8 GR/LB	ENGINE DEW PT. 14.4°C (57.9°F)
ENGINE AIR TEMP. 25.6°C (78.0°F)	ENGINE ABS. HUM. 10.6 G/KG (73.9 GR/LB)	NOX HUMIDITY C.F. .997
		DRY-TO-WET C.F. .979

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1208.4
TOT. BLOWER RATE SCMM (SCFM)	33.65 (1188.1)
TOT. 90MM RATE SCMM (SCFM)	.04 (1.26)
TOT. 20X20 RATE SCMM (SCFM)	1.25 (44.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.10 (3.37)
TOTAL FLOW STD. CU. METRES(SCF)	705.4 (24907.)
HC SAMPLE METER/RANGE/PPM	4.3/ 84/ 21.33
HC BCKGRD METER/RANGE/PPM	7.0/ 82/ 7.00
CO SAMPLE METER/RANGE/PPM	29.0/ 13/ 26.11
CO BCKGRD METER/RANGE/PPM	.8/ 13/ .75
CO2 SAMPLE METER/RANGE/PCT	77.6/ 11/ .6796
CO2 BCKGRD METER/RANGE/PCT	8.6/ 11/ .0507
NOX SAMPLE METER/RANGE/PPM (D)	.3/ 83/ 24.18
NOX BCKGRD METER/RANGE/PPM	.2/ 2/ .21
DILUTION FACTOR	19.47
HC CONCENTRATION PPM	14.69
CO CONCENTRATION PPM	24.66
CO2 CONCENTRATION PCT	.6315
NOX CONCENTRATION PPM	23.47
HC MASS GRAMS	5.999
CO MASS GRAMS	20.249
CO2 MASS GRAMS	8148.71
NOX MASS GRAMS	31.574
FUEL KG (LB)	2.597 (5.72)
KW HR (HP HR)	7.21 (9.67)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.832(.620) (.62) (CONT)	90 MM FILTER NUMBERS	P90-57	P90-58
BSCO G/KW HR (G/HP HR)	2.808(2.094) (2.09)	90 MM FILTER WT. GAINS (MG)	2.068	.181
BSNOX G/KW HR (G/HP HR)	4.379(3.265) (3.27) (CONT)	PARTICULATE GRAMS/TEST	2.216	
PART. G/KW HR (G/HP HR)	.307(.229) (.23)			
BSFC KG/KW HR (LB/HP HR)	.360(.592)			
WORK KW HR (HP HR)	7.21(9.67)			
BSCO2 G/KW HR (G/HP HR)	1130. (843.)			

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER	TEST C10926B8 RUN	DIESEL 2D EM-1809-F
ENGINE MODEL 0 ARMY GM 6.L	DATE 9/26/94 TIME 15:10	HCR 1.91 FID RES. FAC. 1.000
ENGINE 6.2 L(378. CID) V-8	COMPUTER PROGRAM HDT 3.2-R	H .138 C .862 O .000 X .000
ENGINE CYCLE DIESEL	CELL 8 BAG CART 1	ENGINE OIL
ENGINE SERIAL H126642		

BAROMETER 739.4 MM HG (29.11 IN HG)	CVS: 75.0°F RH 44.0 PCT AH 59.2 GR/LB	ENGINE DEW PT. 14.2°C (57.6°F)
ENGINE AIR TEMP. 25.6°C (78.0°F)	ENGINE ABS. HUM. 10.4 G/KG (73.1 GR/LB)	NOX HUMIDITY C.F. .995
		DRY-TO-WET C.F. .980

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1207.8
TOT. BLOWER RATE SCMM (SCFM)	33.58 (1185.9)
TOT. 90MM RATE SCMM (SCFM)	.04 (1.27)
TOT. 20X20 RATE SCMM (SCFM)	1.25 (44.1)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.10 (3.42)
TOTAL FLOW STD. CU. METRES(SCF)	703.9 (24854.)
HC SAMPLE METER/RANGE/PPM	3.9/ 84/ 19.55
HC BCKGRD METER/RANGE/PPM	6.6/ 82/ 6.60
CO SAMPLE METER/RANGE/PPM	29.5/ 13/ 26.57
CO BCKGRD METER/RANGE/PPM	1.9/ 13/ 1.77
CO2 SAMPLE METER/RANGE/PCT	78.1/ 11/ .6859
CO2 BCKGRD METER/RANGE/PCT	9.2/ 11/ .0545
NOX SAMPLE METER/RANGE/PPM (D)	.3/ 83/ 24.13
NOX BCKGRD METER/RANGE/PPM	.1/ 2/ .10
DILUTION FACTOR	19.29
HC CONCENTRATION PPM	13.29
CO CONCENTRATION PPM	24.17
CO2 CONCENTRATION PCT	.6342
NOX CONCENTRATION PPM	23.55
HC MASS GRAMS	5.418
CO MASS GRAMS	19.807
CO2 MASS GRAMS	8166.75
NOX MASS GRAMS	31.541
FUEL KG (LB)	2.602 (5.74)
KW HR (HP HR)	7.25 (9.72)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.747(.557) (.56) (CONT)	90 MM FILTER NUMBERS	P90-59 P90-60
BSCO G/KW HR (G/HP HR)	2.733(2.038) (2.04)	90 MM FILTER WT. GAINS (MG)	2.119 .181
BSNOX G/KW HR (G/HP HR)	4.352(3.245) (3.24) (CONT)	PARTICULATE GRAMS/TEST	2.241
PART. G/KW HR (G/HP HR)	.309(.231) (.23)		
BSFC KG/KW HR (LB/HP HR)	.359(.590)		
WORK KW HR (HP HR)	7.25(9.72)		
BSCO2 G/KW HR (G/HP HR)	1127. (840.)		

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER	TEST R0926B8 RUN	DIESEL 2D EM-1749-F
ENGINE MODEL 0 ARMY GM 6.L	DATE 9/26/94 TIME	HCR 1.78 FID RES. FAC. 1.000
ENGINE 6.2 L(378. CID) V-8	COMPUTER PROGRAM HDT 3.2-R	H .130 C .870 O .000 X .000
ENGINE CYCLE DIESEL	CELL 8 BAG CART 1	ENGINE OIL
ENGINE SERIAL H126642		

BAROMETER 737.9 MM HG (29.05 IN HG)	CVS: 72.0°F RH 46.0 PCT AH 55.3 GR/LB	ENGINE DEW PT. 13.9°C (57.1°F)
ENGINE AIR TEMP. 25.0°C (77.0°F)	ENGINE ABS. HUM. 10.3 G/KG (71.9 GR/LB)	NOX HUMIDITY C.F. .992
		DRY-TO-WET C.F. .981

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1208.2
TOT. BLOWER RATE SCMM (SCFM)	33.68 (1189.4)
TOT. 90MM RATE SCMM (SCFM)	.04 (1.26)
TOT. 20X20 RATE SCMM (SCFM)	1.26 (44.4)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.09 (3.27)
TOTAL FLOW STD. CU. METRES(SCF)	706.2 (24935.)
HC SAMPLE METER/RANGE/PPM	3.7/ 84/ 18.59
HC BCKGRD METER/RANGE/PPM	7.7/ 82/ 7.70
CO SAMPLE METER/RANGE/PPM	25.6/ 13/ 23.02
CO BCKGRD METER/RANGE/PPM	.3/ 13/ .28
CO2 SAMPLE METER/RANGE/PCT	79.3/ 11/ .7011
CO2 BCKGRD METER/RANGE/PCT	7.9/ 11/ .0464
NOX SAMPLE METER/RANGE/PPM (D)	.3/ 83/ 24.56
NOX BCKGRD METER/RANGE/PPM	.1/ 2/ .10
DILUTION FACTOR	19.36
HC CONCENTRATION PPM	11.29
CO CONCENTRATION PPM	22.11
CO2 CONCENTRATION PCT	.6571
NOX CONCENTRATION PPM	24.00
HC MASS GRAMS	4.574
CO MASS GRAMS	18.178
CO2 MASS GRAMS	8488.92
NOX MASS GRAMS	32.152
FUEL KG (LB)	2.677 (5.90)
KW HR (HP HR)	7.32 (9.82)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.625(.466) (.47) (CONT)	90 MM FILTER NUMBERS P90-61 P90-62
BSCO G/KW HR (G/HP HR)	2.482(1.851) (1.85)	90 MM FILTER WT. GAINS (MG) 2.952 .201
BSNOX G/KW HR (G/HP HR)	4.391(3.274) (3.27) (CONT)	PARTICULATE GRAMS/TEST 3.104
PART. G/KW HR (G/HP HR)	.424(.316) (.32)	
BSFC KG/KW HR (LB/HP HR)	.366(.601)	
WORK KW HR (HP HR)	7.32(9.82)	
BSCO2 G/KW HR (G/HP HR)	1159. (864.)	

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER	TEST R0927A8 RUN	DIESEL 2D EM-1749-F
ENGINE MODEL 0 ARMY GM 6.L	DATE 9/27/94 TIME 9:20	HCR 1.78 FID RES. FAC. 1.000
ENGINE 6.2 L(378. CID) V-8	COMPUTER PROGRAM HDT 3.2-R	H .130 C .870 O .000 X .000
ENGINE CYCLE DIESEL	CELL 8 BAG CART 1	ENGINE OIL
ENGINE SERIAL H126642		

BAROMETER 740.7 MM HG (29.16 IN HG)	CVS: 72.0°F RH 49.0 PCT AH 59.5 GR/LB	ENGINE DEW PT. 14.1°C (57.4°F)
ENGINE AIR TEMP. 25.6°C (78.0°F)	ENGINE ABS. HUM. 10.3 G/KG (72.4 GR/LB)	NOX HUMIDITY C.F. .993
		DRY-TO-WET C.F. .980

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1207.8
TOT. BLOWER RATE SCMM (SCFM)	33.70 (1189.9)
TOT. 90MM RATE SCMM (SCFM)	.04 (1.29)
TOT. 20X20 RATE SCMM (SCFM)	1.26 (44.6)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.10 (3.38)
TOTAL FLOW STD. CU. METRES(SCF)	706.4 (24944.)
HC SAMPLE METER/RANGE/PPM	3.7/ 84/ 18.59
HC BCKGRD METER/RANGE/PPM	7.0/ 82/ 7.00
CO SAMPLE METER/RANGE/PPM	27.9/ 13/ 25.11
CO BCKGRD METER/RANGE/PPM	1.1/ 13/ 1.03
CO2 SAMPLE METER/RANGE/PCT	79.2/ 11/ .6998
CO2 BCKGRD METER/RANGE/PCT	9.3/ 11/ .0551
NOX SAMPLE METER/RANGE/PPM (D)	.3/ 83/ 24.45
NOX BCKGRD METER/RANGE/PPM	.1/ 2/ .10
DILUTION FACTOR	19.39
HC CONCENTRATION PPM	11.96
CO CONCENTRATION PPM	23.41
CO2 CONCENTRATION PCT	.6475
NOX CONCENTRATION PPM	23.87
HC MASS GRAMS	4.846
CO MASS GRAMS	19.253
CO2 MASS GRAMS	8368.60
NOX MASS GRAMS	32.030
FUEL KG (LB)	2.640 (5.82)
KW HR (HP HR)	7.37 (9.88)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.658(.491) (.49) (CONT)	90 MM FILTER NUMBERS	P90-63 P90-64
BSCO G/KW HR (G/HP HR)	2.613(1.949) (1.95)	90 MM FILTER WT. GAINS (MG)	2.940 .191
BSNOX G/KW HR (G/HP HR)	4.348(3.242) (3.24) (CONT)	PARTICULATE GRAMS/TEST	3.010
PART. G/KW HR (G/HP HR)	.409(.305) (.30)		
BSFC KG/KW HR (LB/HP HR)	.358(.589)		
WORK KW HR (HP HR)	7.37(9.88)		
BSCO2 G/KW HR (G/HP HR)	1136. (847.)		

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER	TEST C20927A8 RUN	DIESEL 2D EM-1816-F
ENGINE MODEL 0 ARMY GM 6.L	DATE 9/27/94 TIME	HCR 1.91 FID RES. FAC. 1.000
ENGINE 6.2 L(378. CID) V-8	COMPUTER PROGRAM HDT 3.2-R	H .138 C .862 O .000 X .000
ENGINE CYCLE DIESEL	CELL 8 BAG CART 1	ENGINE OIL
ENGINE SERIAL H126642		

BAROMETER 740.9 MM HG (29.17 IN HG)	CVS: 73.0°F RH 54.0 PCT AH 67.0 GR/LB	ENGINE DEW PT. 15.7°C (60.2°F)
ENGINE AIR TEMP. 25.6°C (78.0°F)	ENGINE ABS. HUM. 11.5 G/KG (80.2 GR/LB)	NOX HUMIDITY C.F. 1.014
		DRY-TO-WET C.F. .978

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1207.8
TOT. BLOWER RATE SCMM (SCFM)	33.71 (1190.2)
TOT. 90MM RATE SCMM (SCFM)	.04 (1.27)
TOT. 20X20 RATE SCMM (SCFM)	1.25 (44.3)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.09 (3.33)
TOTAL FLOW STD. CU. METRES(SCF)	706.4 (24944.)
HC SAMPLE METER/RANGE/PPM	3.0/ 84/ 14.84
HC BCKGRD METER/RANGE/PPM	5.6/ 82/ 5.60
CO SAMPLE METER/RANGE/PPM	24.2/ 13/ 21.76
CO BCKGRD METER/RANGE/PPM	.0/ 13/ .00
CO2 SAMPLE METER/RANGE/PCT	77.5/ 11/ .6784
CO2 BCKGRD METER/RANGE/PCT	8.8/ 11/ .0520
NOX SAMPLE METER/RANGE/PPM (D)	.3/ 83/ 23.25
NOX BCKGRD METER/RANGE/PPM	.0/ 2/ .00
DILUTION FACTOR	19.53
HC CONCENTRATION PPM	9.53
CO CONCENTRATION PPM	21.09
CO2 CONCENTRATION PCT	.6290
NOX CONCENTRATION PPM	22.74
HC MASS GRAMS	3.898
CO MASS GRAMS	17.347
CO2 MASS GRAMS	8129.26
NOX MASS GRAMS	31.147
FUEL KG (LB)	2.587 (5.70)
KW HR (HP HR)	7.20 (9.65)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.542(.404) (.40) (CONT)	
BSCO G/KW HR (G/HP HR)	2.411(1.798) (1.80)	
BSNOX G/KW HR (G/HP HR)	4.328(3.228) (3.23) (CONT)	
PART. G/KW HR (G/HP HR)	.361(.269) (.27)	
BSFC KG/KW HR (LB/HP HR)	.360(.591)	
WORK KW HR (HP HR)	7.20(9.65)	
BSCO2 G/KW HR (G/HP HR)	1130. (842.)	

90 MM FILTER NUMBERS	P90-65	P90-66
90 MM FILTER WT. GAINS (MG)	2.465	.200
PARTICULATE GRAMS/TEST	2.599	

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER
ENGINE MODEL 0 ARMY GM 6.L
ENGINE 6.2 L(378. CID) V-8
ENGINE CYCLE DIESEL
ENGINE SERIAL H126642

TEST C20927C8 RUN
DATE 9/27/94 TIME 14:40
COMPUTER PROGRAM HDT 3.2-R
CELL 8 BAG CART 1

DIESEL 2D EM-1816-F
HCR 1.91 FID RES. FAC. 1.000
H .138 C .862 O .000 X .000
ENGINE OIL

BAROMETER 739.4 MM HG (29.11 IN HG)
ENGINE AIR TEMP. 27.2°C (81.0°F)

CVS: 75.0°F RH 51.0 PCT AH 68.6 GR/LB
ENGINE ABS. HUM. 11.0 G/KG (77.2 GR/LB)

ENGINE DEW PT. 15.1°C (59.1°F)
NOX HUMIDITY C.F. 1.006
DRY-TO-WET C.F. .978

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1207.5
TOT. BLOWER RATE SCMM (SCFM)	33.59 (1185.9)
TOT. 90MM RATE SCMM (SCFM)	.04 (1.28)
TOT. 20X20 RATE SCMM (SCFM)	1.22 (43.1)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.09 (3.35)
TOTAL FLOW STD. CU. METRES(SCF)	703.1 (24828.)
HC SAMPLE METER/RANGE/PPM	4.6/ 84/ 22.95
HC BCKGRD METER/RANGE/PPM	13.7/ 82/ 13.70
CO SAMPLE METER/RANGE/PPM	24.2/ 13/ 21.76
CO BCKGRD METER/RANGE/PPM	1.0/ 13/ .94
CO2 SAMPLE METER/RANGE/PCT	77.6/ 11/ .6796
CO2 BCKGRD METER/RANGE/PCT	8.7/ 11/ .0514
NOX SAMPLE METER/RANGE/PPM (D)	.3/ 83/ 23.90
NOX BCKGRD METER/RANGE/PPM	.1/ 2/ .10
DILUTION FACTOR	19.47
HC CONCENTRATION PPM	9.96
CO CONCENTRATION PPM	20.24
CO2 CONCENTRATION PCT	.6309
NOX CONCENTRATION PPM	23.27
HC MASS GRAMS	4.054
CO MASS GRAMS	16.564
CO2 MASS GRAMS	8115.05
NOX MASS GRAMS	31.475
FUEL KG (LB)	2.582 (5.69)
KW HR (HP HR)	7.22 (9.68)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.562(.419) (.42) (CONT)
BSCO G/KW HR (G/HP HR)	2.295(1.711) (1.71)
BSNOX G/KW HR (G/HP HR)	4.360(3.252) (3.25) (CONT)
PART. G/KW HR (G/HP HR)	.368(.274) (.27)
BSFC KG/KW HR (LB/HP HR)	.358(.588)
WORK KW HR (HP HR)	7.22(9.68)
BSCO2 G/KW HR (G/HP HR)	1124. (838.)

90 MM FILTER NUMBERS	P90-69	P90-70
90 MM FILTER WT. GAINS (MG)	2.556	.189
PARTICULATE GRAMS/TEST	2.654	

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER	TEST R0927B8 RUN	DIESEL 2D EM-1749-F
ENGINE MODEL 0 ARMY GM 6.L	DATE 9/27/94 TIME 17:15	HCR 1.78 FID RES. FAC. 1.000
ENGINE 6.2 L(378. CID) V-8	COMPUTER PROGRAM HDT 3.2-R	H .130 C .870 O .000 X .000
ENGINE CYCLE DIESEL	CELL 8 BAG CART 1	ENGINE OIL
ENGINE SERIAL H126642		

BAROMETER 739.9 MM HG (29.13 IN HG)	CVS: 77.0°F RH 42.0 PCT AH 60.5 GR/LB	ENGINE DEW PT. 14.3°C (57.7°F)
ENGINE AIR TEMP. 27.2°C (81.0°F)	ENGINE ABS. HUM. 10.5 G/KG (73.3 GR/LB)	NOX HUMIDITY C.F. .996
		DRY-TO-WET C.F. .980

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1208.0
TOT. BLOWER RATE SCMM (SCFM)	33.66 (1188.6)
TOT. 90MM RATE SCMM (SCFM)	.04 (1.30)
TOT. 20X20 RATE SCMM (SCFM)	1.22 (43.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.09 (3.35)
TOTAL FLOW STD. CU. METRES(SCF)	704.9 (24891.)
HC SAMPLE METER/RANGE/PPM	2.6/ 84/ 13.11
HC BCKGRD METER/RANGE/PPM	4.6/ 82/ 4.60
CO SAMPLE METER/RANGE/PPM	24.3/ 13/ 21.85
CO BCKGRD METER/RANGE/PPM	.1/ 13/ .09
CO2 SAMPLE METER/RANGE/PCT	78.5/ 11/ .6909
CO2 BCKGRD METER/RANGE/PCT	7.3/ 11/ .0427
NOX SAMPLE METER/RANGE/PPM (D)	.3/ 83/ 24.52
NOX BCKGRD METER/RANGE/PPM	.1/ 2/ .10
DILUTION FACTOR	19.66
HC CONCENTRATION PPM	8.74
CO CONCENTRATION PPM	21.18
CO2 CONCENTRATION PCT	.6504
NOX CONCENTRATION PPM	23.93
HC MASS GRAMS	3.537
CO MASS GRAMS	17.378
CO2 MASS GRAMS	8387.39
NOX MASS GRAMS	32.122
FUEL KG (LB)	2.644 (5.83)
KW HR (HP HR)	7.29 (9.78)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.485(.362) (.36) (CONT)	90 MM FILTER NUMBERS	P90-71	P90-72
BSCO G/KW HR (G/HP HR)	2.383(1.777) (1.78)	90 MM FILTER WT. GAINS (MG)	2.758	.195
BSNOX G/KW HR (G/HP HR)	4.405(3.284) (3.28) (CONT)	PARTICULATE GRAMS/TEST	2.806	
PART. G/KW HR (G/HP HR)	.385(.287) (.29)			
BSFC KG/KW HR (LB/HP HR)	.363(.596)			
WORK KW HR (HP HR)	7.29(9.78)			
BSCO2 G/KW HR (G/HP HR)	1150. (858.)			

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER	TEST R0928A8 RUN	DIESEL 2D EM-1749-F
ENGINE MODEL 0 ARMY GM 6.L	DATE 9/28/94 TIME 9:30	HCR 1.78 FID RES. FAC. 1.000
ENGINE 6.2 L(378. CID) V-8	COMPUTER PROGRAM HDT 3.2-R	H .130 C .870 0 .000 X .000
ENGINE CYCLE DIESEL	CELL 8 BAG CART 1	ENGINE OIL
ENGINE SERIAL H126642		

BAROMETER 742.7 MM HG (29.24 IN HG)	CVS: 73.0°F RH 58.0 PCT AH 71.6 GR/LB	ENGINE DEW PT. 14.3°C (57.8°F)
ENGINE AIR TEMP. 26.7°C (80.0°F)	ENGINE ABS. HUM. 10.5 G/KG (73.3 GR/LB)	NOX HUMIDITY C.F. .996
		DRY-TO-WET C.F. .977

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1207.9
TOT. BLOWER RATE SCMM (SCFM)	33.84 (1195.1)
TOT. 90MM RATE SCMM (SCFM)	.04 (1.29)
TOT. 20X20 RATE SCMM (SCFM)	1.27 (44.7)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.10 (3.38)
TOTAL FLOW STD. CU. METRES(SCF)	709.5 (25053.)
HC SAMPLE METER/RANGE/PPM	3.3/ 84/ 16.45
HC BCKGRD METER/RANGE/PPM	5.2/ 82/ 5.20
CO SAMPLE METER/RANGE/PPM	24.9/ 13/ 22.39
CO BCKGRD METER/RANGE/PPM	.3/ 13/ .28
CO2 SAMPLE METER/RANGE/PCT	79.4/ 11/ .7024
CO2 BCKGRD METER/RANGE/PCT	8.5/ 11/ .0501
NOX SAMPLE METER/RANGE/PPM (D)	.3/ 83/ 24.12
NOX BCKGRD METER/RANGE/PPM	.1/ 2/ .10
DILUTION FACTOR	19.33
HC CONCENTRATION PPM	11.52
CO CONCENTRATION PPM	21.41
CO2 CONCENTRATION PCT	.6548
NOX CONCENTRATION PPM	23.48
HC MASS GRAMS	4.689
CO MASS GRAMS	17.687
CO2 MASS GRAMS	8499.67
NOX MASS GRAMS	31.715
FUEL KG (LB)	2.681 (5.91)
KW HR (HP HR)	7.39 (9.91)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.634(.473) (.47) (CONT)	90 MM FILTER NUMBERS	P90-73 P90-74
BSCO G/KW HR (G/HP HR)	2.393(1.785) (1.78)	90 MM FILTER WT. GAINS (MG)	2.739 .188
BSNOX G/KW HR (G/HP HR)	4.292(3.200) (3.20) (CONT)	PARTICULATE GRAMS/TEST	2.818
PART. G/KW HR (G/HP HR)	.381(.284) (.28)		
BSFC KG/KW HR (LB/HP HR)	.363(.596)		
WORK KW HR (HP HR)	7.39(9.91)		
BSCO2 G/KW HR (G/HP HR)	1150. (858.)		

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER
ENGINE MODEL 0 ARMY GM 6.L
ENGINE 6.2 L(378. CID) V-8
ENGINE CYCLE DIESEL
ENGINE SERIAL H126642

TEST C30928B8 RUN
DATE 9/28/94 TIME 15:20
COMPUTER PROGRAM HDT 3.2-R
CELL 8 BAG CART 1

DIESEL 2D EM-1818-F
HCR 1.91 FID RES. FAC. 1.000
H .138 C .862 O .000 X .000
ENGINE OIL

BAROMETER 740.7 MM HG (29.16 IN HG)
ENGINE AIR TEMP. 26.7°C (80.0°F)

CVS: 77.0°F RH 46.0 PCT AH 65.1 GR/LB
ENGINE ABS. HUM. 10.6 G/KG (74.0 GR/LB)

ENGINE DEW PT. 14.4°C (58.0°F)
NOX HUMIDITY C.F. .997
DRY-TO-WET C.F. .979

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1208.0
TOT. BLOWER RATE SCMM (SCFM)	33.70 (1189.9)
TOT. 90MM RATE SCMM (SCFM)	.04 (1.29)
TOT. 20X20 RATE SCMM (SCFM)	1.22 (43.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.10 (3.37)
TOTAL FLOW STD. CU. METRES(SCF)	705.6 (24916.)
HC SAMPLE METER/RANGE/PPM	3.3/ 84/ 16.39
HC BCKGRD METER/RANGE/PPM	6.7/ 82/ 6.70
CO SAMPLE METER/RANGE/PPM	24.2/ 13/ 21.76
CO BCKGRD METER/RANGE/PPM	.1/ 13/ .09
CO2 SAMPLE METER/RANGE/PCT	77.5/ 11/ .6784
CO2 BCKGRD METER/RANGE/PCT	8.1/ 11/ .0476
NOX SAMPLE METER/RANGE/PPM (D)	.3/ 83/ 23.82
NOX BCKGRD METER/RANGE/PPM	.1/ 2/ .10
DILUTION FACTOR	19.53
HC CONCENTRATION PPM	10.03
CO CONCENTRATION PPM	21.06
CO2 CONCENTRATION PCT	.6331
NOX CONCENTRATION PPM	23.21
HC MASS GRAMS	4.099
CO MASS GRAMS	17.302
CO2 MASS GRAMS	8173.27
NOX MASS GRAMS	31.248
FUEL KG (LB)	2.601 (5.73)
KW HR (HP HR)	7.15 (9.59)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.573(.427) (.43) (CONT)
BSCO G/KW HR (G/HP HR)	2.419(1.804) (1.80)
BSNOX G/KW HR (G/HP HR)	4.370(3.258) (3.26) (CONT)
PART. G/KW HR (G/HP HR)	.302(.225) (.23)
BSFC KG/KW HR (LB/HP HR)	.364(.598)
WORK KW HR (HP HR)	7.15(9.59)
BSCO2 G/KW HR (G/HP HR)	1143. (852.)

90 MM FILTER NUMBERS	P90-77	P90-78
90 MM FILTER WT. GAINS (MG)	2.088	.169
PARTICULATE GRAMS/TEST	2.159	

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA HOT-TRANS ENGINE EMISSION RESULTS — PROJECT NO. 02-5137-506

ENGINE NUMBER	TEST C30928C8 RUN	DIESEL 2D EM-1818-F
ENGINE MODEL 0 ARMY GM 6.L	DATE 9/28/94 TIME 16:00	HCR 1.91 FID RES. FAC. 1.000
ENGINE 6.2 L(378. CID) V-8	COMPUTER PROGRAM HDT 3.2-R	H .138 C .862 0 .000 X .000
ENGINE CYCLE DIESEL	CELL 8 BAG CART 1	ENGINE OIL
ENGINE SERIAL H126642		

BAROMETER 740.7 MM HG (29.16 IN HG)	CVS: 77.0°F RH 46.0 PCT AH 65.1 GR/LB	ENGINE DEW PT. 14.4°C (58.0°F)
ENGINE AIR TEMP. 26.7°C (80.0°F)	ENGINE ABS. HUM. 10.6 G/KG (74.0 GR/LB)	NOX HUMIDITY C.F. .997
		DRY-TO-WET C.F. .979

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1208.0
TOT. BLOWER RATE SCMM (SCFM)	33.74 (1191.4)
TOT. 90MM RATE SCMM (SCFM)	.04 (1.30)
TOT. 20X20 RATE SCMM (SCFM)	1.20 (42.3)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.10 (3.37)
TOTAL FLOW STD. CU. METRES(SCF)	706.1 (24932.)
HC SAMPLE METER/RANGE/PPM	3.3/ 84/ 16.57
HC BCKGRD METER/RANGE/PPM	6.2/ 82/ 6.20
CO SAMPLE METER/RANGE/PPM	24.8/ 13/ 22.30
CO BCKGRD METER/RANGE/PPM	.0/ 13/ .00
CO2 SAMPLE METER/RANGE/PCT	77.5/ 11/ .6784
CO2 BCKGRD METER/RANGE/PCT	8.2/ 11/ .0483
NOX SAMPLE METER/RANGE/PPM (D)	.3/ 83/ 23.62
NOX BCKGRD METER/RANGE/PPM	.1/ 2/ .10
DILUTION FACTOR	19.53
HC CONCENTRATION PPM	10.68
CO CONCENTRATION PPM	21.67
CO2 CONCENTRATION PCT	.6326
NOX CONCENTRATION PPM	23.02
HC MASS GRAMS	4.369
CO MASS GRAMS	17.816
CO2 MASS GRAMS	8171.01
NOX MASS GRAMS	31.005
FUEL KG (LB)	2.601 (5.73)
KW HR (HP HR)	7.17 (9.61)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.610(.455) (.45) (CONT)	90 MM FILTER NUMBERS	P90-79	P90-80
BSCO G/KW HR (G/HP HR)	2.486(1.854) (1.85)	90 MM FILTER WT. GAINS (MG)	2.154	.190
BSNOX G/KW HR (G/HP HR)	4.327(3.226) (3.23) (CONT)	PARTICULATE GRAMS/TEST	2.235	
PART. G/KW HR (G/HP HR)	.312(.233) (.23)			
BSFC KG/KW HR (LB/HP HR)	.363(.597)			
WORK KW HR (HP HR)	7.17(9.61)			
BSCO2 G/KW HR (G/HP HR)	1140. (850.)			

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER	TEST R0928B8 RUN	DIESEL 2D EM-1749-F
ENGINE MODEL 0 ARMY GM 6.L	DATE 9/28/94 TIME 18:15	HCR 1.78 FID RES. FAC. 1.000
ENGINE 6.2 L(378. CID) V-8	COMPUTER PROGRAM HDT 3.2-R	H .130 C .870 O .000 X .000
ENGINE CYCLE DIESEL	CELL 8 BAG CART 1	ENGINE OIL
ENGINE SERIAL H126642		

BAROMETER 740.2 MM HG (29.14 IN HG)	CVS: 76.0°F RH 45.0 PCT AH 62.1 GR/LB	ENGINE DEW PT. 14.7°C (58.5°F)
ENGINE AIR TEMP. 27.8°C (82.0°F)	ENGINE ABS. HUM. 10.8 G/KG (75.4 GR/LB)	NOX HUMIDITY C.F. 1.001
		DRY-TO-WET C.F. .980

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1207.9
TOT. BLOWER RATE SCMM (SCFM)	33.67 (1188.7)
TOT. 90MM RATE SCMM (SCFM)	.04 (1.29)
TOT. 20X20 RATE SCMM (SCFM)	1.25 (44.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.10 (3.36)
TOTAL FLOW STD. CU. METRES(SCF)	705.5 (24910.)
HC SAMPLE METER/RANGE/PPM	3.0/ 84/ 15.02
HC BCKGRD METER/RANGE/PPM	5.8/ 82/ 5.80
CO SAMPLE METER/RANGE/PPM	24.5/ 13/ 22.03
CO BCKGRD METER/RANGE/PPM	.6/ 13/ .56
CO2 SAMPLE METER/RANGE/PCT	78.7/ 11/ .6935
CO2 BCKGRD METER/RANGE/PCT	7.7/ 11/ .0452
NOX SAMPLE METER/RANGE/PPM (D)	.3/ 83/ 25.06
NOX BCKGRD METER/RANGE/PPM	.1/ 2/ .10
DILUTION FACTOR	19.59
HC CONCENTRATION PPM	9.51
CO CONCENTRATION PPM	20.89
CO2 CONCENTRATION PCT	.6506
NOX CONCENTRATION PPM	24.45
HC MASS GRAMS	3.851
CO MASS GRAMS	17.159
CO2 MASS GRAMS	8396.63
NOX MASS GRAMS	33.028
FUEL KG (LB)	2.647 (5.84)
KW HR (HP HR)	7.33 (9.83)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.525(.392) (.39) (CONT)
BSCO G/KW HR (G/HP HR)	2.341(1.746) (1.75)
BSNOX G/KW HR (G/HP HR)	4.506(3.360) (3.36) (CONT)
PART. G/KW HR (G/HP HR)	.369(.275) (.27)
BSFC KG/KW HR (LB/HP HR)	.361(.594)
WORK KW HR (HP HR)	7.33(9.83)
BSCO2 G/KW HR (G/HP HR)	1145. (854.)

90 MM FILTER NUMBERS	P90-81	P90-82
90 MM FILTER WT. GAINS (MG)	2.643	.175
PARTICULATE GRAMS/TEST	2.702	

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER	TEST R0929A8 RUN	DIESEL 2D EM-1749-F
ENGINE MODEL 0 ARMY GM 6.L	DATE 9/29/94 TIME 9:20	HCR 1.78 FID RES. FAC. 1.000
ENGINE 6.2 L(378. CID) V-8	COMPUTER PROGRAM HDT 3.2-R	H .130 C .870 O .000 X .000
ENGINE CYCLE DIESEL	CELL 8 BAG CART 1	ENGINE OIL
ENGINE SERIAL H126642		

BAROMETER 742.2 MM HG (29.22 IN HG)	CVS: 71.0°F RH 49.0 PCT AH 56.5 GR/LB	ENGINE DEW PT. 13.9°C (57.0°F)
ENGINE AIR TEMP. 26.1°C (79.0°F)	ENGINE ABS. HUM. 10.2 G/KG (71.2 GR/LB)	NOX HUMIDITY C.F. .990
		DRY-TO-WET C.F. .981

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1207.7
TOT. BLOWER RATE SCMM (SCFM)	33.76 (1192.1)
TOT. 90MM RATE SCMM (SCFM)	.04 (1.32)
TOT. 20X20 RATE SCMM (SCFM)	1.26 (44.5)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.10 (3.37)
TOTAL FLOW STD. CU. METRES(SCF)	707.6 (24985.)
HC SAMPLE METER/RANGE/PPM	3.2/ 84/ 15.85
HC BCKGRD METER/RANGE/PPM	5.7/ 82/ 5.70
CO SAMPLE METER/RANGE/PPM	28.3/ 13/ 25.47
CO BCKGRD METER/RANGE/PPM	3.9/ 13/ 3.62
CO2 SAMPLE METER/RANGE/PCT	79.7/ 11/ .7062
CO2 BCKGRD METER/RANGE/PCT	9.8/ 11/ .0583
NOX SAMPLE METER/RANGE/PPM (D)	.3/ 83/ 24.07
NOX BCKGRD METER/RANGE/PPM	.1/ 2/ .10
DILUTION FACTOR	19.22
HC CONCENTRATION PPM	10.45
CO CONCENTRATION PPM	21.35
CO2 CONCENTRATION PCT	.6510
NOX CONCENTRATION PPM	23.51
HC MASS GRAMS	4.243
CO MASS GRAMS	17.591
CO2 MASS GRAMS	8426.54
NOX MASS GRAMS	31.504
FUEL KG (LB)	2.657 (5.86)
KW HR (HP HR)	7.40 (9.92)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.574(.428) (.43) (CONT)	
BSCO G/KW HR (G/HP HR)	2.378(1.773) (1.77)	
BSNOX G/KW HR (G/HP HR)	4.259(3.176) (3.18) (CONT)	
PART. G/KW HR (G/HP HR)	.365(.272) (.27)	
BSFC KG/KW HR (LB/HP HR)	.359(.591)	
WORK KW HR (HP HR)	7.40(9.92)	
BSCO2 G/KW HR (G/HP HR)	1139. (849.)	

90 MM FILTER NUMBERS	P90-83	P90-84
90 MM FILTER WT. GAINS (MG)	2.693	.181
PARTICULATE GRAMS/TEST	2.701	

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA HOT-TRANS ENGINE EMISSION RESULTS

PROJECT NO. 02-5137-506

ENGINE NUMBER
ENGINE MODEL 0 ARMY GM 6.L
ENGINE 6.2 L(378. CID) V-8
ENGINE CYCLE DIESEL
ENGINE SERIAL H126642

TEST C30929A8 RUN
DATE 9/29/94 TIME 12:40
COMPUTER PROGRAM HDT 3.2-R
CELL 8 BAG CART 1

DIESEL 2D EM-1818-F
HCR 1.91 FID RES. FAC. 1.000
H .138 C .862 O .000 X .000
ENGINE OIL

BAROMETER 742.2 MM HG (29.22 IN HG)
ENGINE AIR TEMP. 27.2°C (81.0°F)

CVS: 73.0°F RH 39.0 PCT AH 48.8 GR/LB
ENGINE ABS. HUM. 10.2 G/KG (71.7 GR/LB)

ENGINE DEW PT. 14.0°C (57.2°F)
NOX HUMIDITY C.F. .992
DRY-TO-WET C.F. .982

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1208.7
TOT. BLOWER RATE SCMM (SCFM)	33.72 (1190.6)
TOT. 90MM RATE SCMM (SCFM)	.04 (1.35)
TOT. 20X20 RATE SCMM (SCFM)	1.27 (44.7)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.09 (3.35)
TOTAL FLOW STD. CU. METRES(SCF)	707.4 (24980.)
HC SAMPLE METER/RANGE/PPM	3.2/ 84/ 15.78
HC BCKGRD METER/RANGE/PPM	6.2/ 82/ 6.20
CO SAMPLE METER/RANGE/PPM	22.9/ 13/ 20.59
CO BCKGRD METER/RANGE/PPM	.1/ 13/ .09
CO2 SAMPLE METER/RANGE/PCT	77.6/ 11/ .6796
CO2 BCKGRD METER/RANGE/PCT	8.5/ 11/ .0501
NOX SAMPLE METER/RANGE/PPM (D)	.3/ 83/ 24.21
NOX BCKGRD METER/RANGE/PPM	.4/ 2/ .42
DILUTION FACTOR	19.50
HC CONCENTRATION PPM	9.90
CO CONCENTRATION PPM	19.97
CO2 CONCENTRATION PCT	.6321
NOX CONCENTRATION PPM	23.39
HC MASS GRAMS	4.056
CO MASS GRAMS	16.446
CO2 MASS GRAMS	8179.94
NOX MASS GRAMS	31.378
FUEL KG (LB)	2.603 (5.74)
KW HR (HP HR)	7.22 (9.68)

TOTAL RESULTS

BSHC	G/KW HR (G/HP HR)	.562(	.419) (	.42)	(CONT)
BSCO	G/KW HR (G/HP HR)	2.278(	1.699) (	1.70)	
BSNOX	G/KW HR (G/HP HR)	4.347(	3.242) (	3.24)	(CONT)
PART.	G/KW HR (G/HP HR)	.302(	.225) (	.23)	
BSFC	KG/KW HR (LB/HP HR)	.361(	.593)		
WORK	KW HR (HP HR)	7.22(	9.68)		
BSCO2	G/KW HR (G/HP HR)	1133. (	845.)		

90 MM FILTER NUMBERS	P90-85	P90-86
90 MM FILTER WT. GAINS (MG)	2.187	.177
PARTICULATE GRAMS/TEST	2.178	

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER	TEST C30929B8 RUN	DIESEL 2D EM-1818-F
ENGINE MODEL 0 ARMY GM 6.L	DATE 9/29/94 TIME 12:55	HCR 1.91 FID RES. FAC. 1.000
ENGINE 6.2 L(378. CID) V-8	COMPUTER PROGRAM HDT 3.2-R	H .138 C .862 O .000 X .000
ENGINE CYCLE DIESEL	CELL 8 BAG CART 1	ENGINE OIL
ENGINE SERIAL H126642		

BAROMETER 741.9 MM HG (29.21 IN HG)	CVS: 72.0°F RH 42.0 PCT AH 50.5 GR/LB	ENGINE DEW PT. 13.8°C (56.9°F)
ENGINE AIR TEMP. 27.2°C (81.0°F)	ENGINE ABS. HUM. 10.1 G/KG (71.0 GR/LB)	NOX HUMIDITY C.F. .990
		DRY-TO-WET C.F. .982

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1207.8
TOT. BLOWER RATE SCMM (SCFM)	33.77 (1192.4)
TOT. 90MM RATE SCMM (SCFM)	.04 (1.32)
TOT. 20X20 RATE SCMM (SCFM)	1.26 (44.6)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.10 (3.41)
TOTAL FLOW STD. CU. METRES(SCF)	707.9 (24996.)
HC SAMPLE METER/RANGE/PPM	3.3/ 84/ 16.69
HC BCKGRD METER/RANGE/PPM	6.5/ 82/ 6.50
CO SAMPLE METER/RANGE/PPM	24.0/ 13/ 21.58
CO BCKGRD METER/RANGE/PPM	.7/ 13/ .66
CO2 SAMPLE METER/RANGE/PCT	77.9/ 11/ .6834
CO2 BCKGRD METER/RANGE/PCT	8.5/ 11/ .0501
NOX SAMPLE METER/RANGE/PPM (D)	.3/ 83/ 22.44
NOX BCKGRD METER/RANGE/PPM	.2/ 2/ .21
DILUTION FACTOR	19.39
HC CONCENTRATION PPM	10.52
CO CONCENTRATION PPM	20.38
CO2 CONCENTRATION PCT	.6358
NOX CONCENTRATION PPM	21.84
HC MASS GRAMS	4.314
CO MASS GRAMS	16.798
CO2 MASS GRAMS	8234.28
NOX MASS GRAMS	29.259
FUEL KG (LB)	2.621 (5.78)
KW HR (HP HR)	7.24 (9.71)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.596(.444) (.44) (CONT)	90 MM FILTER NUMBERS	P90-87	P90-88
BSCO G/KW HR (G/HP HR)	2.320(1.730) (1.73)	90 MM FILTER WT. GAINS (MG)	2.206	.170
BSNOX G/KW HR (G/HP HR)	4.041(3.013) (3.01) (CONT)	PARTICULATE GRAMS/TEST	2.229	
PART. G/KW HR (G/HP HR)	.308(.230) (.23)			
BSFC KG/KW HR (LB/HP HR)	.362(.595)			
WORK KW HR (HP HR)	7.24(9.71)			
BSCO2 G/KW HR (G/HP HR)	1137. (848.)			

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
EPA HOT-TRANS ENGINE EMISSION RESULTS PROJECT NO. 02-5137-506

ENGINE NUMBER	TEST R0929B8 RUN	DIESEL 2D EM-1749-F
ENGINE MODEL 0 ARMY GM 6.L	DATE 9/29/94 TIME 15:50	HCR 1.78 FID RES. FAC. 1.000
ENGINE 6.2 L(378. CID) V-8	COMPUTER PROGRAM HDT 3.2-R	H .130 C .870 O .000 X .000
ENGINE CYCLE DIESEL	CELL 8 BAG CART 1	ENGINE OIL
ENGINE SERIAL H126642		

BAROMETER 740.4 MM HG (29.15 IN HG)	CVS: 73.0°F RH 39.0 PCT AH 49.0 GR/LB	ENGINE DEW PT. 14.1°C (57.3°F)
ENGINE AIR TEMP. 27.2°C (81.0°F)	ENGINE ABS. HUM. 10.3 G/KG (72.2 GR/LB)	NOX HUMIDITY C.F. .993
		DRY-TO-WET C.F. .983

BAG RESULTS

BAG NUMBER	1
TIME SECONDS	1207.3
TOT. BLOWER RATE SCMM (SCFM)	33.69 (1189.5)
TOT. 90MM RATE SCMM (SCFM)	.04 (1.29)
TOT. 20X20 RATE SCMM (SCFM)	1.27 (44.8)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.10 (3.36)
TOTAL FLOW STD. CU. METRES(SCF)	706.0 (24929.)
HC SAMPLE METER/RANGE/PPM	3.1/ 84/ 15.38
HC BCKGRD METER/RANGE/PPM	5.2/ 82/ 5.20
CO SAMPLE METER/RANGE/PPM	23.0/ 13/ 20.68
CO BCKGRD METER/RANGE/PPM	.6/ 13/ .56
CO2 SAMPLE METER/RANGE/PCT	77.6/ 11/ .6796
CO2 BCKGRD METER/RANGE/PCT	8.1/ 11/ .0476
NOX SAMPLE METER/RANGE/PPM (D)	.3/ 83/ 24.82
NOX BCKGRD METER/RANGE/PPM	.0/ 2/ .00
DILUTION FACTOR	19.99
HC CONCENTRATION PPM	10.44
CO CONCENTRATION PPM	19.63
CO2 CONCENTRATION PCT	.6343
NOX CONCENTRATION PPM	24.39
HC MASS GRAMS	4.231
CO MASS GRAMS	16.130
CO2 MASS GRAMS	8193.02
NOX MASS GRAMS	32.694
FUEL KG (LB)	2.583 (5.69)
KW HR (HP HR)	7.46 (10.00)

TOTAL RESULTS

BSHC G/KW HR (G/HP HR)	.567(.423) (.42) (CONT)
BSCO G/KW HR (G/HP HR)	2.163(1.613) (1.61)
BSNOX G/KW HR (G/HP HR)	4.384(3.269) (3.27) (CONT)
PART. G/KW HR (G/HP HR)	.352(.263) (.26)
BSFC KG/KW HR (LB/HP HR)	.346(.569)
WORK KW HR (HP HR)	7.46(10.00)
BSCO2 G/KW HR (G/HP HR)	1099. (819.)

90 MM FILTER NUMBERS	P90-89	P90-90
90 MM FILTER WT. GAINS (MG)	2.550	.187
PARTICULATE GRAMS/TEST	2.625	

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